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AN UPDATE OF THE DISCRETE ADDRESS BEACON SYSTEM (DABS) ALTERNAT--ETC(U)

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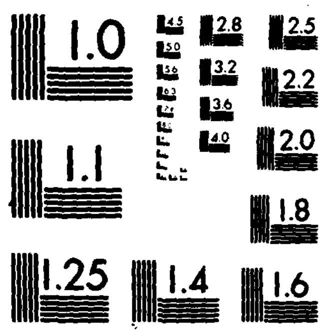

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(6) AN UPDATE OF THE DISCRETE ADDRESS BEACON SYSTEM (DABS) ALTERNATIVES STUDY

Marvin ... Kal
Martin ... Ziecey

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16. Abstract

This document is an update of an earlier "Study of Alternative Beacon Based Surveillance and Data Link Systems," ~~FAA-EM-74-7, April 1974.~~ It is based on the numerous studies, analyses, simulations, and flight tests conducted since the original study. The document uses the findings from that large body of work to summarize the rationale that led to the selection and continued development of DABS + ATARS + BCAS as the preferred approach to improving the surveillance, air-ground communications, and collision avoidance functions of the ATC system and provide the basis for further improvements in the automation of the ATC system. Hypothetical scenarios heavily weighted in favor of the most competitive alternative, SAB + VHF D/L + ATARS, are presented as a basis for cost comparisons. DABS + ATARS + BCAS is shown to be the most cost effective approach.

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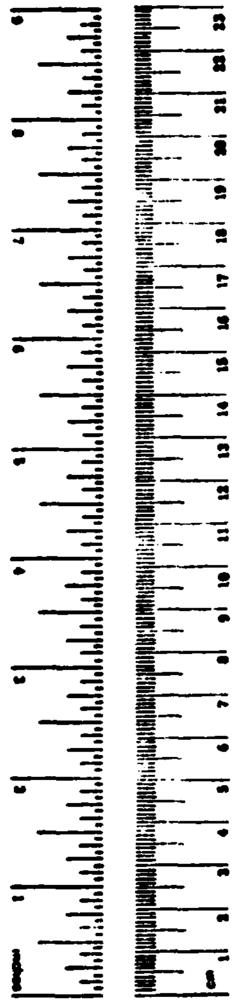
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

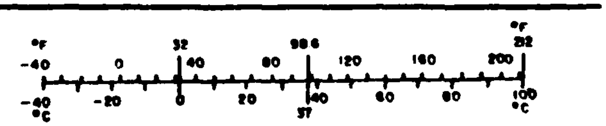
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

This report presents a review of the numerous studies, analyses, tests and evaluations conducted over the period 1974-1978 dealing with the Discrete Address Beacon System (DABS) and with alternative approaches to improving the performance of the beacon surveillance system, providing a data link for improved air-ground-air communications, and improving the collision avoidance capabilities of the ATC system. The results summarized herein have led to the selection of the Discrete Address Beacon System (DABS), the Automatic Traffic Advisory and Resolution Service (ATARS), and the Beacon Collision Avoidance System (BCAS) as the major elements of the FAA's development program to provide for those improvements.

In dealing with such a complex subject in as simple and direct way as possible, it has been necessary to omit the details and to summarize some of the critical findings and conclusions. The reader interested in researching the subject to gain a better insight into each of the complex issues may do so by examining the referenced documents.

2. BACKGROUND

In August 1974, the Office of the Secretary of Transportation published a report on the results of a "Review of the Upgraded Third Generation Air Traffic Control Development" programs of the FAA.(1) In essence, the report concluded that the "planned E&D programs of the FAA should be continued." The report went on to identify certain actions that the FAA should undertake in order to provide the basis for future OST decisions on the FAA's E&D program and on FAA's plans for implementing the products of the E&D program.

One of the actions identified within the OST report was that the FAA should continue the development of the Discrete Address Beacon System (DABS) with Intermittent Positive Control (since renamed Automatic Traffic Advisory and Resolution Service -- ATARS) and Collision Avoidance Systems (CAS). The OST report went on to state that the FAA should initiate additional, more comprehensive studies of other alternatives so that all options could be evaluated with equal confidence. Some of the specific actions indicated in the OST Study were as follows:

- Analyze and evaluate the cost of "Improved ATCRBS" with "Selective Address."

- Evaluate, and establish realistic cost estimates, for the use of a VHF data link both separately and in connection with the Selective Address/Improved ATCRBS for ATARS.

- Provide an overall comparison of alternative ways of achieving the collective objectives of the DABS + ATARS, and CAS* programs.

Since the publication of the OST report in August 1974, the FAA has conducted or sponsored numerous studies and symposiums to:

- Examine various collision avoidance alternatives including ATARS and CAS.

- Obtain user views on the selection of the preferred collision avoidance system(s) and on the need for air-to-ground data link.

---

* At the time of the referenced DOT report, the acronym "CAS" was used to refer to what subsequently became known as Airborne Collision Avoidance System (ACAS) and Beacon Collision Avoidance System (BCAS).

- Develop cost estimates of various technical approaches.

- Track trends in safety related data.

- Identify potential increases in controller productivity (and reduced ATC costs) that might be realized through the use of advanced automation and the use of air-to-ground data link.

In-depth analysis and extensive flight test of BCAS, ACAS, and ATARS concepts and designs were undertaken and completed in order to evaluate those systems as alternative or complementary approaches to providing additional midair collision avoidance capabilities.[2,3]

The costs and the benefits of the future ATC system incorporating DABS and ATARS were analyzed, from a full systems perspective.[4]

Cost estimates of avionics associated with various alternative systems were prepared by the ARINC Research Corporation for the FAA.[5,6,7,8,9] Comparisons of the cost of alternatives using various implementation scenarios were conducted.[10,11]

Analysis of safety related data such as midair collisions, near midair collisions and ATC System Errors indicated the need for some way to back-up today's ATC system and automatically provide the pilot with warning and advisory services both in en route airspace and in

high density terminal airspace designated as Terminal Control Areas or Terminal Radar Service Areas.[12,13]

Three independent studies of the increases in controller productivity that might be realized with the implementation of advanced automation concepts and air-ground data link were conducted.[14,15,16] Those studies indicated that substantial reduction in controller costs could be realized in the en route part of the ATC system and in high density terminal areas, which have ARTS-III facilities, through the combined use of data link and the automatic generation and delivery of ATC messages.

Collectively, all of the individual analyses referred to above constitute a substantial body of work in the comparison of alternatives to DABS and ATARS as means to improve collision avoidance service, to provide improved surveillance and to provide a data link to support both the improved collision avoidance service and future improvements in the automation of other ATC services. Additionally, those studies indicated the need to supplement ATARS with an airborne collision avoidance system that would work outside the surveillance coverage of the ATC system and in low density airspace where the cost of coverage by an ATARS ground system would

be prohibitive. A Beacon Collision Avoidance System (BCAS) has been selected for that purpose and a national standard is being developed.

This document summarizes past work and adds a comparison of the costs of implementing DABS plus ATARS with the costs of implementing its closest competitive alternative--Improved ATCRBS with "Selective Addressing" plus a VHF data link plus ATARS.

3. APPROACH AND SCOPE

This analysis is presented in four basic steps.

1. All reasonable alternatives will be listed and described in brief.

2. An initial screening will be made on the basis of performance and those that do not meet the basic needs will be set aside as not warranting further examination.

3. The Aircraft Separation Assurance systems in the remaining alternatives will be examined in greater detail and screened in order to further reduce the number of alternatives to be examined in depth.

4. The two final alternatives which emerge from the preceding three steps will be described and compared. In order to be on the conservative side with respect to the DABS + ATARS alternative, all assumptions will be weighted heavily in favor of the other alternative.

This document deals primarily with the selection of the preferred alternative for achieving the desired operational capability. Numerous other studies have been made with regard to the basic need to achieve improved ATC productivity, safety, capacity, delay reduction, etc. and on the vital role that improvements in surveillance and communications will play in supporting the advanced

automation features aimed at satisfying those needs. In general, however, the subject of the collective benefits of the advanced automation programs and the supportive improvements in communications and surveillance are not addressed in depth in this report. Instead, the discussions of needs and benefits is aimed at developing a fundamental understanding of why improvements are needed and how the alternatives discussed herein might be deployed within the ATC system to best support those needs. Thus, this document must be viewed as a cost effective comparison of alternatives aimed at providing improvements necessary to achieve certain operational performance. It is not a cost benefit study.

4. THE NEED FOR IMPROVED SURVEILLANCE, AIR-GROUND DATA LINK, AND COLLISION AVOIDANCE SYSTEMS

Through a series of improvements, the surveillance provided by ATCRBS and supplemented by primary radar and the air-ground communications provided by the VHF air-ground voice system are basically adequate to support today's level of automation in the ATC system at today's traffic levels. However, there is a fundamental need to make improvements in beacon surveillance and air-ground communications to achieve advanced automation capabilities in order to increase ATC productivity, improve safety, provide additional services to users, and, to a lesser degree, increase capacity and reduce delay.

4.1 Increasing Controller Productivity

Studies conducted during the past two years for the FAA [14,15,16] have concluded that very substantial increases in controller productivity can be realized through the application of advanced automation at the en route Air Traffic Control Centers (ARTCCs) and at the more highly automated terminal facilities (ARTS-III). Those studies all assumed the availability of improved surveillance and an air-ground data link for the automatic exchange of ATC messages and data between the ATC facilities and the aircraft receiving ATC services.

One study indicated that savings of as much as 92,000 controller years might be realized in the ARTCC facilties in a post data link

era from 1985-2000. Potential savings in the terminal facilities were estimated to be as high as 22,000 controller years over that same period (Figures 4-1 and 4-2). Another study indicated that en route facilities would reach saturation in the 1980's without the benefit of advanced automation and data link and that the disbenefits of the lack of automation and data link would be an inability to support the growth in air traffic. A third study, limited to the 30 busiest terminal areas, concluded that significant savings could be realized at those facilities through advanced automation with data link and improved surveillance.

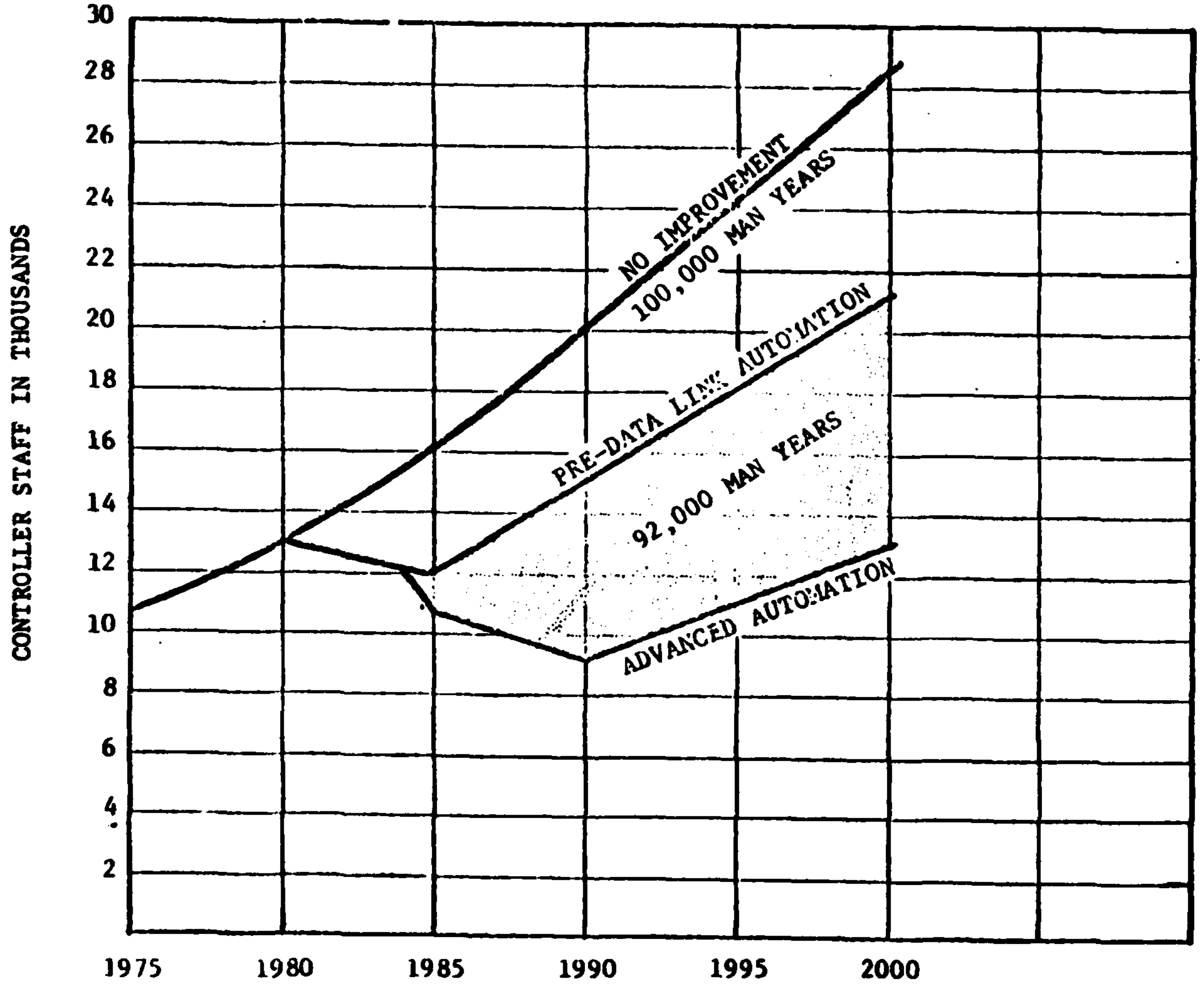
4.2 Improving Safety

The subject of providing improved aircraft separation assurance continues to be a topic of the highest interest to the FAA and to users of the ATC system. There is substantial agreement among the parties concerned that additional measures should be taken to reduce the chance of midair collisions and to preclude the occurrence of a major catastrophe such as a midair collision involving large body air carrier aircraft loaded with hundreds of passengers, particularly in view of ever increasing aviation operations. This is in spite of a very enviable midair collision safety record that has been realized within U.S. airspace during recent years (Figure 4-3).

The definition as to what is needed and what constitutes a reasonable program has been a major challenge since none of the technical

FIGURE 4-1

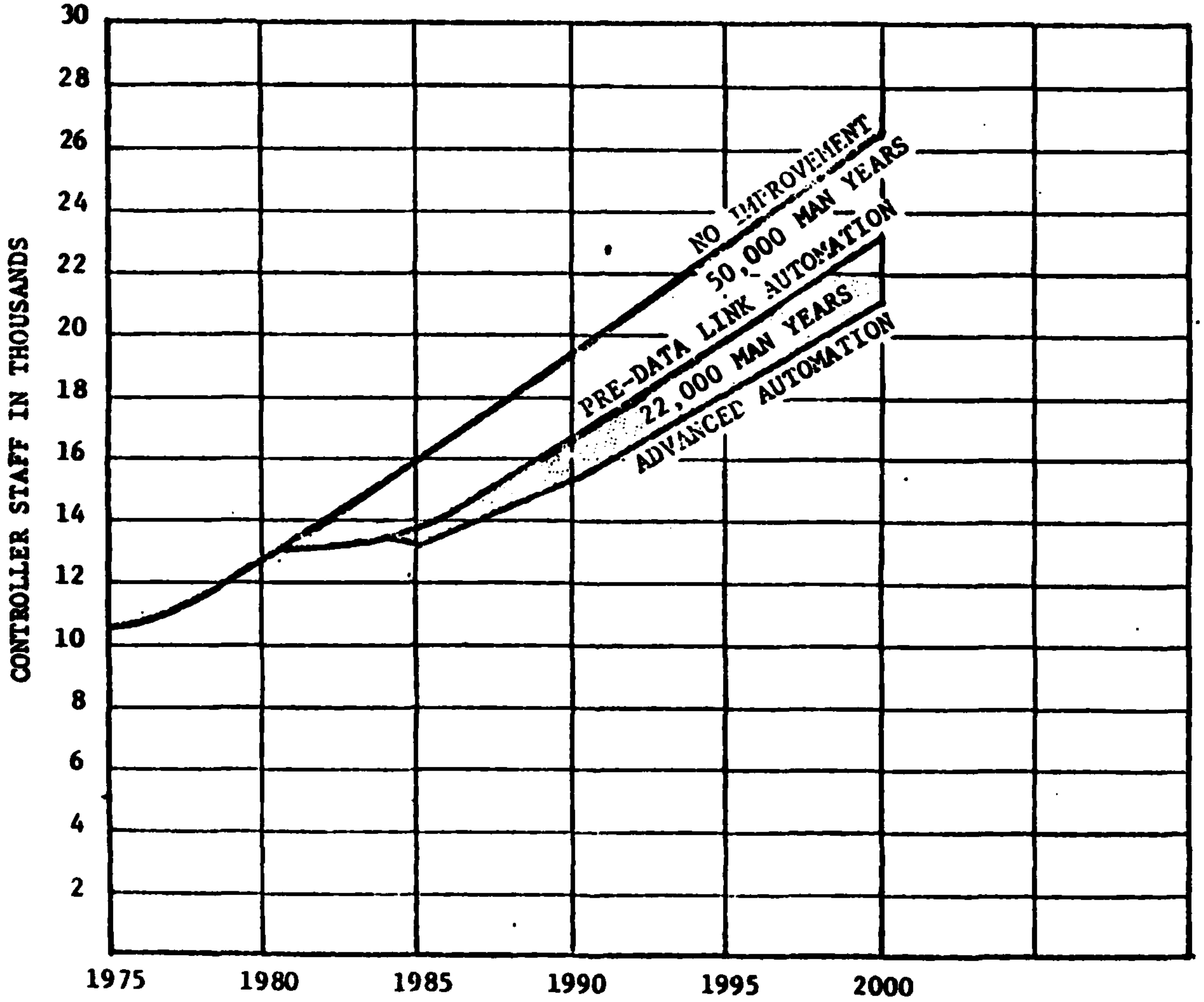
POTENTIAL SAVINGS IN EN ROUTE SYSTEM STAFFING



SOURCE: Reference 16.

FIGURE 4-2

POTENTIAL SAVINGS IN TERMINAL SYSTEM O&M
COST DUE TO UG3RD IMPROVEMENTS



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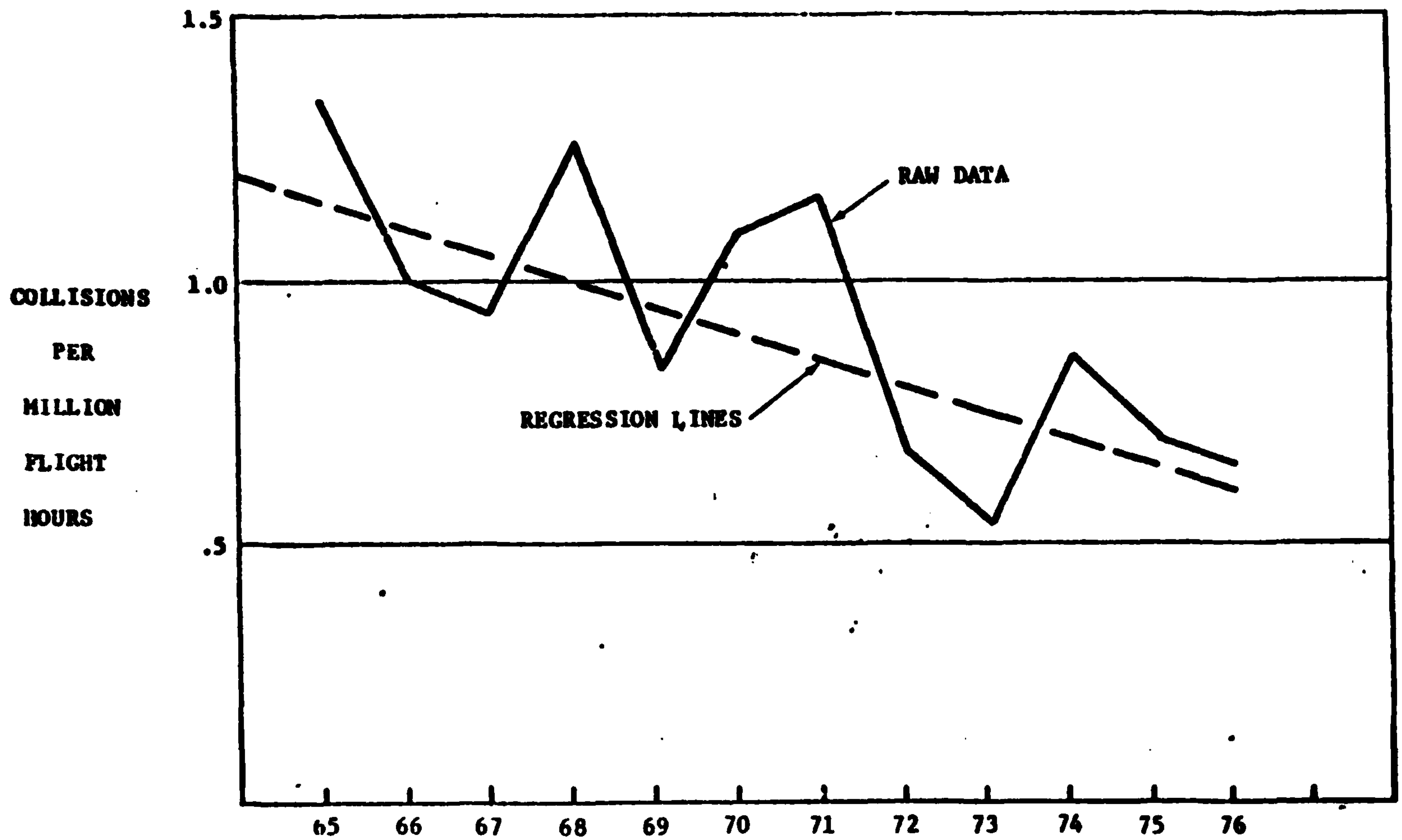


FIGURE 4-3

MIDAIR COLLISIONS PER MILLION FLIGHT HOURS

approaches possible with today's technology offer a completely satisfactory solution to all users. In order to define a reasonable program, the FAA has spent a considerable amount of time and effort in examining all feasible alternatives.

In view of the lack of a single satisfactory solution capable of operating effectively in all airspace, the FAA has also conducted extensive studies of past midair collisions, near midair collisions, and ATC System Errors to provide additional insight as to the parts of the airspace of most concern and the performance that needs to be achieved in system design. Earlier examinations of midair collision statistics had indicated that the terminal area airspace was of greatest concern with lesser risk in other parts of the airspace.(17,18) Since then questions have been raised about the validity of relying on that data too heavily because midair collisions are such rare events and because there was some chance that recent changes to the ATC systems might have caused some changes as to the areas of airspace of greatest concern. In particular, the thought has been expressed that the introduction of TCA/TRSA rules and procedures in the higher density terminal airspace, and the introduction of the controller Conflict Alert function in the NAS Stage A and ARTS III facilities might have changed the nature of the threat to the point where conclusions based on an examination of previous collisions might have been wrong. In order to examine those

questions, and in the absence of any statistically significant number of recent midair collisions, studies were made both of recent near midair collisions and of recent ATC System Errors (SEs).

An examination of the near midair collision data indicates that the introduction of TCA/TRSA areas have not eliminated the need for additional collision avoidance services in those areas. For example, an examination of 178 near midair collisions reports submitted to the FAA during the first part of 1975 indicated that 30 NMACs occurred within TCA/TRSA airspace. Eight of those 30 NMACs involved air carriers (Figure 4-4). Thus, based on an analysis of NMAC reports, it can be concluded that there is still a need for backup to the controller in TCA/TRSA airspace. This conclusion is supported by data gathered by NASA as part of its Aviation Safety Reporting System (ASRS). The fourth quarterly report by NASA on the ASRS data(19) states that "a large fraction of ASRS reports describe occurrences in terminal airspace. Of 136 reports that related to TCA and TRSA operating environments, 70% involved potential conflicts among aircraft.....One-third involved ATC and controller problems."

The number of SE's reports submitted from the en route and terminal facilities for the years 1970-1977 were also examined. The data was analyzed to see if there were any trends that would indicate that recent improvements to the ATC system, including Conflict Alert, had improved ATC performance to the point where the need for additional

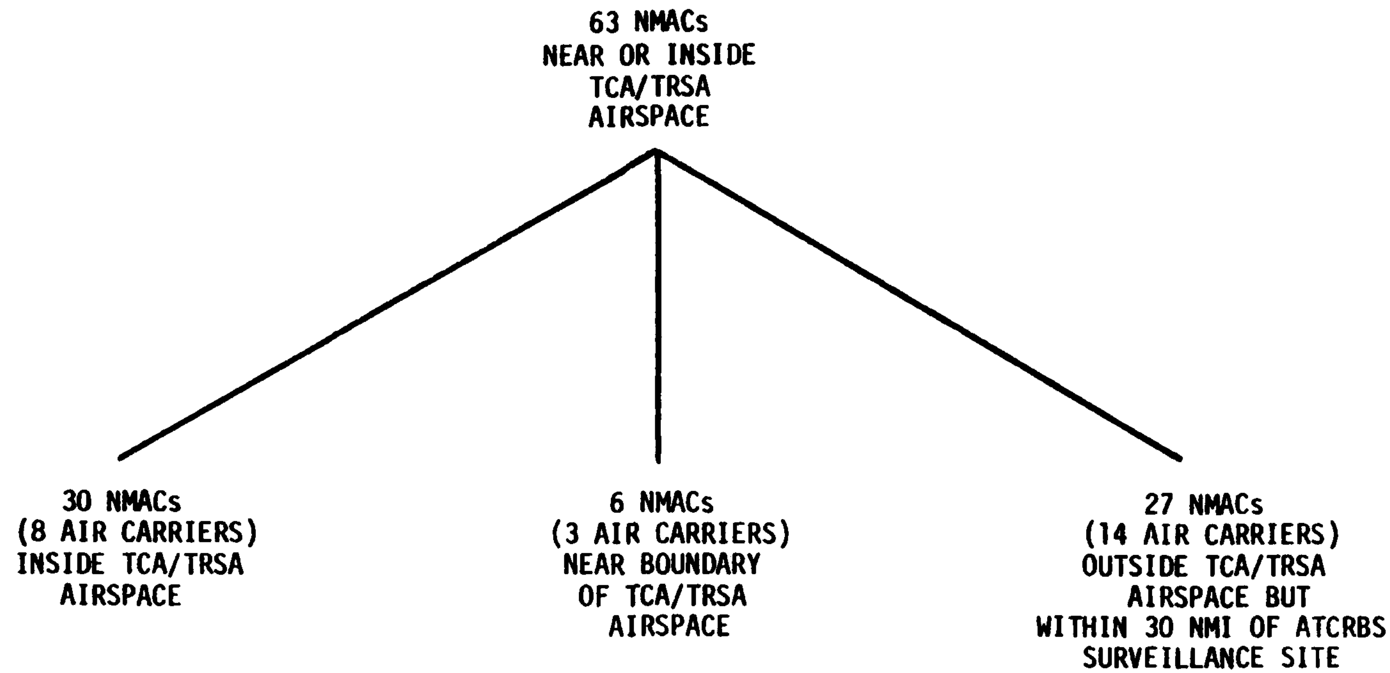


FIGURE 4-4

NEAR MIDAIR COLLISIONS (NMACs)
OCCURRING INSIDE OF OR CLOSE TO TCA/TRSA AIRSPACE
(FROM SAMPLE OF 178 NMACs -- CY 1975)

collision avoidance protection might not be needed between aircraft flying under ATC control.

All of the above leads to the conclusions that:

- o there is a widely recognized need for additional collision avoidance protection.

- o it cannot be concluded that the introduction of Conflict Alert has eliminated the need for an automatic backup to the ATC system in en route or terminal airspace.

- o the implementation of TCA/TRSA airspace has not eliminated the need for an automatic backup to the ATC system in the high density terminal airspace.

- o the need for improved collision avoidance advisories exists even under conditions where one controller is involved who has position and altitude information available on both aircraft, hence procedural and/or regulatory rules to assure that those conditions will exist does not offer a complete solution.

4.3 Providing Additional Services

The primary need for improving air-ground communications via the use of data link is based on the need to provide the communications vehicle needed to support technical approaches for improving controller productivity and improving safety as discussed above. In addition there is substantial merit in using the data link to provide for other services as well. The FAA is in the process of defining more specifically what those additional services should be. A list of possibilities have been developed by the FAA and are currently being studied. The applications under consideration are listed in Table 4-1.

It is premature to say that the listing in Table 4-1 constitutes an accurate listing of all the potential uses for the data link beyond those for the basic advanced automation and collision avoidance needs. This list does, however, provide an indication of services

the FAA and users may find to be desirable and important -- especially if the data link is already available for other essential purposes. Thus, while all of the additional services cannot now be viewed as a hard requirement, it can be stated that if a data link is needed and implemented then that data link should be designed to have the capacity to accommodate those services.

TABLE 4-1

POTENTIAL ADDITIONAL SERVICES VIA USE OF DATA LINK

1. WIND SHEAR INFORMATION TO AIRCRAFT ON FINAL APPROACH AND PRIOR TO TAKEOFF.
2 HAZARDOUS WEATHER BOTH TERMINAL AND EN ROUTE
3. RVR ON FINAL APPROACH AND PRIOR TO TAKEOFF.
4. STATUS OF CATEGORY II/III CRITICAL AREAS (PROTECTED OR NOT PROTECTED).
5. TRANSMISSION AND CONFIRMATION OF CLEARANCES.
6. ALTITUDE ASSIGNMENT CONFIRMATION.
7. ACTIVE RUNWAY WIND TO AIRCRAFT ON FINAL APPROACH AND PRIOR TO TAKEOFF.
8. REALTIME (ROUTINE) WEATHER DATA.
9. AIRCRAFT INPUT FOR ADVANCED METERING AND SPACING.
10. CONTROLLER UPDATED NAVIGATIONAL DISPLAYS.
11. ATIS, NOTAM, FLIGHT AND FIELD INFORMATION.
12. AIR-TO-AIR CONFLICT DETECTION.
13. AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE.
14. MSAW AND CONFLICT ALERT REALTIME TO AIRCRAFT.
15. TERMINAL FORECASTS.
16. PIREPS.
17. AIR DERIVED WEATHER.

4.4 Providing Incentive to Users to Equip

One of the major challenges in selecting the course of action to satisfy the ATC needs expressed above is the selection of a technical approach that will keep costs to the users sufficiently low that they will elect to install the equipment on their own initiative.

If the users of the ATC system do not perceive of the benefits as being worth the price and if the FAA does not mandate equipage, then it will not be possible to fully achieve the objective of increasing controller productivity and reducing controller costs through the use of advanced automation. These considerations place an extra incentive on the selection of a technical approach that will minimize the incremental costs to users to obtain the new services.

4.5 The Need -- Summary

The established needs, or requirements, for improving beacon surveillance, providing an air-ground data link, and providing improved separation assurance are based on an anlysis of what improvements must be made in those supporting functions to enable the FAA to implement advanced automation concepts to:

- o Improve controller productivity and reduce O&M costs.

- o Improve Safety

- o Increase Capacity

In addition to those established needs, improvements in beacon surveillance and air-ground communications should:

- o Support the implementation of other automated ATC features that would provide additional services to the pilot or provide useful data to the ATC system.

- o Provide the means to support the transmission of airport surface, runway occupancy, and air situation data to the pilot.

- o Preclude the possibility of aircraft delay in the en route airspace due to the lack of a data link and a resultant inability to implement advanced automation concepts which depend on the automatic delivering of ATC messages.

Finally, if at all possible, the technical approach selected to satisfy the ATC needs should be implementable through avionics sufficiently low in cost to cause the users of the ATC system to view the benefits as worthy of the incremental cost and to take the initiative to install the equipment.

5. THE ALTERNATIVES

During the past several years, numerous technical approaches for making improvements in the three functional areas of beacon surveillance, air-ground communications, and pilot warning and separation assurance services have been identified or postulated. For the purpose of this summary report, only those concepts which have been seriously considered during recent years are included here.

5.1 The Individual Contenders

The primary contenders for making improvements in each of the three functional areas of beacon surveillance, communications, and aircraft separation assurance are identified in Table 5-1.

5.1.1 Alternatives for Improving Beacon Surveillance

- Improved ATCRBS: Reduced susceptibility to interference and increased azimuth accuracy achieved by modifying today's ATCRBS system to include monopulse detection capacility. No transponder changes are required.

- SAB (4096): Susceptibility to synchronous garble reduced by replacing ATCRBS ground electronics with new electronics having a selective addressing capability once a specific code has been assigned on a flight-by-flight basis. Uses improved ATCRBS antennas. Includes a monopulse detection capability.

TABLE 5-1

ELEMENTS FOR STRUCTURING VARIOUS ALTERNATIVES
(BASIS FOR AS MANY AS 30 DIFFERENT ALTERNATIVE CONFIGURATIONS)

SURVEILLANCE	DATA LINK	SEPARATION ASSURANCE	
		DENSE AIRSPACE	OUTSIDE ATC
IMPROVED ATCRBS ALONE	VHF (ARINC) (ACARS)*	ATARS	ACAS
SELECTIVE ADDRESS	VHF (NEW) (HIGH CAPACITY)	ACAS	BCAS
DABS	DABS	BCAS	

*AUTOMATIC COMMUNICATIONS ADDRESSING AND REPORTING SYSTEM (ACARS)

- DABS: Susceptibility to synchronous garble eliminated by replacing ATCRBS ground electronics with new electronics with a discrete addressing capability and an integral data link. Individual aircraft can be assigned a permanent code. Uses improved ATCRBS antennas. Includes a monopulse detection capability.

5.1.2 Alternatives for Improving Air-Ground Communications

- VHF (ARINC-ACARS) -- A 2400 bps data link now offered as a service by ARINC to airlines for company communications purposes. Now being used by some airlines.

- VHF D/L (New) -- A VHF data link capability that could be achieved by developing 4800 or 9600 bps data link modems and using those modems in conjunction with VHF transceivers. Sized to satisfy foreseeable ATC needs including ATARS. If implemented, the facilities would belong to the FAA and operated under FAA control.

- DABS -- A data link operating on today's ATCRBS frequencies and integrated in the DABS design with the discrete addressing capability. Experimental hardware delivered and

under test. Sized to satisfy foreseeable ATC needs including ATARS. Facilities would be owned and operated by the FAA.

5.1.3 Alternatives for Improving Aircraft Separation Assurance

- Airborne Collision Avoidance System (ACAS) -- Increased separation assurance is achieved between any two aircraft, operating in low to medium density airspace - provided both are equipped with ACAS systems including an altitude encoding system. Separation assurance advisories are generated independent of the intent or knowledge of the ATC system. Designs by three companies have been evaluated by the FAA.[20]

- Beacon Collision Avoidance System -- Active (Active BCAS) -- Increased separation assurance is achieved in medium and low density airspace by one aircraft equipped with Active BCAS actively interrogating another aircraft equipped with an ATCRBS, DABS, or SAB transponder with altitude reporting. Separation assurance advisories are generated independent of the ATC system. Flight tests have demonstrated the technical feasibility.[21]

- <u>Beacon Collision Avoidance System -- Full (Full BCAS)</u> -- Increased separation assurance is realized through an airborne unit which has an active mode plus the ability to derive data on other aircraft by listening to ground interrogations and to the replies of other aircraft. The "other aircraft" needs to be equipped with an ATCRBS, SAB, or DABS beacon with an altitude reporting capability. The Full BCAS will provide several features not found in the Active BCAS. The design approach will include many features aimed at allowing the use of the system in higher density airspace than Active BCAS and providing the pilot with a traffic situation display.

- <u>Automatic Traffic Advisory and Resolution Service (ATARS)</u> -- Increased separation assurance is realized for aircraft flying within airspace under surveillance from a ground surveillance site with ATARS equipment, provided that at least one of the two aircraft has an ATARS display and an air-ground data link while the other aircraft is equipped with at least an ATCRBS, SAB, or DABS transponder with altitude reporting. Separation assurance advisories are

provided to the ATC system as well as to the pilot. Experimental hardware/software has been built and tested to demonstrate feasibility.[22]

A quick reference summary of the characteristics of these different elements are shown in Table 5-2, along with a listing of FAA reports which provide the most recent detailed descriptions of the systems.

TABLE 5-2

CHARACTERISTICS OF THE POSSIBLE ELEMENTS

SURVEILLANCE

- IMPROVE ATCRBS ALONE (FAA-EM-74-7, VOL. II, APRIL 1974)
  - STOP SHORT OF MODIFYING AVIONICS
  - EVOLUTIONARY
- IMPROVED ATCRBS WITH SELECTIVE ADDRESS BEACON (FAA-EM-74-7, VOL. II, APRIL 1974)
  - 4096 ADDRESS
  - MOST OF SURVEILLANCE IMPROVEMENT IN DABS
  - NO DATA LINK
  - EVOLUTIONARY
- DABS (FAA-RD-74-189, NOVEMBER 1974)
  - "UNLIMITED ADDRESSES"
  - COMBINED SURVEILLANCE AND DATA LINK UPGRADE
  - EVOLUTIONARY

DATA LINK

- VHF (ARINC) -- AECC PROJECT PAPER 597 -- MARCH 1978
  - ADAPT AIRLINES COMPANY DATA LINK FOR ATC USE
- VHF (NEW) -- FAA-EM-74-7, VOL. II, APRIL 1974
  - HIGHER CAPACITY VHF TO MEET ATARS + ATC DATA LINK NEEDS
- DABS -- FAA-RD-74-189, NOVEMBER 1974
  - DATA LINK FOR ATARS AND ATC NEEDS INTEGRATED WITH SURVEILLANCE IMPROVEMENT

SEPARATION ASSURANCE

- ATARS -- FAA-EM-74-1, REVISION, DATED JULY 1974
  - GROUND BASED CAS COOPERATING WITH ATC
  - BASED ON ANY COMBINATION OF SURVEILLANCE AND DATA LINK
- ACAS -- FAA-RD-76-17
  - INDEPENDENT SELF-CONTAINED
  - PROPOSED BY INDUSTRY (HONEYWELL, McDONALD-DOUGLAS, RCA)
- BCAS -- FAA-EM-78-5, FAA-EM-75-7, FAA-RD-77-98
  - CAS USES ATC BEACON SYSTEM (ATCRBS, DABS, OR SAB)

6. THE INITIAL SCREENING

As indicated in Table 5-1, many different combinations of surveillance, communication and separation assurance alternatives exist as possibilities for simultaneous comparison. However, the number of possibilities can be reduced substantially by examining the capabilities of the various elements in light of performance requirements. In this section, the following candidate elements will be considered and removed from further discussions.

- Improved ATCRBS -- Surveillance
- VHF D/L (ARINC-ACARS) -- Communication
- ACAS -- Collision Avoidance in denser airspace.
- BCAS -- Collision Avoidance in denser airspace.

6.1 Improved ATCRBS Alone

The technical problem known as "synchronous garble" has long been known as an inherent limitation of the ATCRBS system. Simply stated, it is an interference phenomena which causes the quality and reliability of the surveillance information to be degraded when two or more aircraft fly in close proximity. To some degree, computer processing can reduce the severity of this problem. However, it is a phenomena which gets increasingly worse as traffic density increases. Numerous studies and experiments have been conducted as to the projected severity of this problem.[27,28]

FAA analyses conclude that this problem will become severe in the mid to late 1980's. There has been continuing controversy as to when this problem will become intolerable. However, the fundamental knowledge that synchronous garble will cause an unacceptable degradation in ATCRBS performance in the future makes it imprudent to plan a future ATC system on such a controversial foundation. Indeed, one of the most insidious features of this phenomena is that it occurs primarily at the point when high quality surveillance information is most essential -- when two aircraft are flying in close proximity.

As recognized in OST's response to the initial DABS Alternatives Study[27] there is little controversy but that the limitations of ATCRBS itself will inherently limit the future growth and capability of the ATC system. Indeed some form of selective addressing is prudent to introduce. The simplest approach to solving the problem is the Selective Address Beacon which makes it practical to consider the modification of existing ATCRBS transponders on some aircraft, at a modest price.

Based on the above, Improved ATCRBS has been set aside in this document as not being adequate to support the future ATC needs. Hence, the minimal capability deployment considered herein assumes some form of selected addressing will be required at surveillance sites where synchronous garble would otherwise be a problem.

6.2 VHF D/L (ARINC-ACARS)

The airlines have recently implemented a VHF data link, ACARS, for internal company communications. This system is implemented on existing ARINC frequencies. Proposals have been made that this system could also be used to support the future FAA data link needs. However, system capacity analyses conducted in 1974[27] and more recently in 1978[29] have shown that the system does not have enough capacity to satisfy the full range of future ATC needs. Hence, ACARS can be eliminated from further consideration.

6.3 ACAS or BCAS in High Density Airspace

The general subject of collision avoidance will be discussed at length in the next section of this report. However, it is useful to borrow certain conclusions from that section for the purpose of eliminating ACAS and BCAS from consideration with respect to the high density airspace.

Over the past several years, the FAA has conducted in depth testing and studies of various collision avoidance alternatives.[20,21,22] One of the very fundamental conclusions can be brought to bear at this point -- specifically that a totally independent device which does not coordinate with the ground based ATC system is not a

suitable solution for a collision avoidance back up in the high density areas. Such devices have no knowledge of aircraft intent, airspace restrictions, surrounding terrain, operating flight rules, or ATC controller intent. Consequently when used in high density terminal airspace, conflicts with the primary ATC system and potentially unsafe situations can arise.

These independent systems can often give a pilot instructions which conflict with simultaneous control instructions being given by the ATC controller under conditions which, indeed, are completely safe and where a collision avoidance maneuver is neither necessary nor desirable. Such systems can cause a "domino effect" problem in which secondary collision problems are caused as a result of an unplanned maneuver with respect to the rest of the traffic in close proximity to the maneuvering aircraft. Flight restrictions caused by local terrain or airspace configuration as well as surrounding traffic patterns are not considered in such a system.

The limitations of these totally independent systems when operating in high density areas have led to the conclusion that they are not suitable as a back up collision avoidance system in such cases and may, in fact, be potentially hazardous when used under such conditions. Stated differently, any back up collision avoidance system operating in high density airspace must operate cooperatively with the ATC system to eliminate (or minimize) the potential for

conflicting instructions. Thus the FAA considers that neither ACAS or BCAS are fully acceptable solutions in the high density airspace.

The ATARS system, using ground based computers which operate independently of the ATC system is the only collision avoidance alternative which has the potential of overcoming the major limitations of the independent systems. ATARS can be adapted to account for differences in terrain, airspace configurations, operating flight rules, and airport configurations on a site-by-site basis. It can be integrated with the ATC procedures to account for airport configuration, controller intent, etc. The recent integration of Conflict Alert into the ATC system has shown that such site adaptation is needed in order to achieve acceptable operation in high density areas.

In short, ATARS, in conjunction with the improved surveillance and data link alternatives which have not been screened out, promises to be the most productive approach for providing high quality back-up collision avoidance service in the high density areas, and with a system that is also within the cost range of all categories of users.

6.4 The Remaining Alternatives

As a result of the preceding discussion and the referenced supporting analyses, tests, and evaluations, the large number of alternatives that could have been devised from the individual systems identified in can be reduced to a more limited set as shown in Table 6-1.

TABLE 6-1

ALTERNATIVES REMAINING AFTER INITIAL SCREENING CAS SYSTEMS FOR USE IN HIGH DENSITY AIRSPACE

REMAINING ELEMENTS

SURVEILLANCE	DATA LINK	SEPARATION ASSURANCE	
		DENSE AIRSPACE	OUTSIDE ATC
SELECTIVE ADDRESSING PLUS IMPROVED ATARS	VHF (NEW)	ATARS	ACAS
DABS	DABS		BCAS

ALTERNATIVES POSSIBLE WITH REMAINING ELEMENTS

1. SAB + VHF D/L + ATARS + ACAS
2. SAB + VHF D/L + ATARS + BCAS
3. DABS + ATARS + ACAS
4. DABS + ATARS + BCAS

7. SCREENING THE COLLISION AVOIDANCE SYSTEMS

The alternatives remaining after the initial screening as shown in Table 6-1 can be reduced still further by further screening of the collision avoidance alternatives -- ACAS, BCAS, and ATARS, all of which have been a part of the FAA's Aircraft Separation Assurance program.

The question of collision avoidance has been an important focus of FAA's development and planning activities during the period 1973 to the present. Extensive, in depth analyses have been conducted considering various approaches toward solving this problem.[3,9,27] These analyses have been supplemented by extensive costing studies, simulations, and flight test programs.[6,7,8,20,21,22] Formal consultative planning conferences have been held with the user community at various times in which this complex problem has been discussed and debated.[3] Formal position papers have been solicited and received from various elements of the user community dealing with this important question. In this section the essential elements of this problem will be discussed and the rationale for the selection of ATARS and BCAS as the FAA's major development emphasis will be presented.

During the past 10-15 years, numerous airborne collision avoidance systems (ACAS) have been proposed which operate independently of the ATC system and provide the pilot with collision avoidance advisories.

Those systems were intended to provide the pilot with last-minute collision avoidance service to protect against blunders of the ATC system for aircraft under ATC control and against midair collisions for aircraft not under ATC surveillance and control. Three such systems have been developed by industry and evaluated by the FAA. They are:

RCA	-	SECANT
McDonell Douglas	-	EROS
Honeywell	-	AVOIDS

All three of these systems were designed to provide the pilot with a last moment advisory that he should climb or dive. The advisory is given within approximately 30 seconds of the potential collision.

The FAA conducted extensive analysis, tests, and simulations of each of the ACAS designs and selected the AVOIDS system offered by Honeywell as the best and most cost effective of the three.[20] However, the FAA decided to not proceed with the implementation of AVOIDS but, instead, elected to proceed with the development of alternative designs on the use of the airborne transponder element of the ground based ATC surveillance systems -- ATCRBS, DABS, or SAB. Those designs have become collectively known as BCAS systems.

The rationale behind this decision was explained in detail at the November 1976 User's Consultative Planning Conference.[3] The key points included in that rationale are shown in Table 7-1. Each of the points of comparison will be discussed in the following sections. Several of the tables and figures are the same as those used in presentations to industry at the referenced consultative planning conference.

7.1 ACAS vs. BCAS

The key points considered by the FAA in its comparison of the ACAS, Active BCAS and Full BCAS designs are discussed below. Throughout this discussion a distinction will be made between the two forms of BCAS - Active and Full. The Active BCAS represents a more limited capability than the Full BCAS, hence the origin of the terms.

7.1.1 Operational Limitations

As discussed in the previous section, both the ACAS and Active BCAS systems have been shown to suffer from excessive false or unwanted alarms in high density terminal areas. These systems have no knowledge of pilot intent, ATC procedures, surrounding terrain limitations, etc. Full BCAS has a similar limitation although not as severe. The ACAS and Active BCAS systems are range-only systems and

TABLE 7-1

COMPARISON OF ACAS VS BCAS

KEY POINTS	ACAS	ACTIVE BCAS	FULL BCAS
1. OPERATIONAL LIMITATIONS	DENSE AIRSPACE	DENSE AIRSPACE	DENSER AIRSPACE
2. SERVICES AREAS -- WITHOUT ICAO APPROVAL	CONUS	WORLDWIDE	WORLDWIDE
3. DISPLAY TO PILOT	CLIMB/DIVE	CLIMB/DIVE	VERTICAL/HORIZONTAL (SITUATION DISPLAY)
4. COOPERATIVE ELEMENT	ACAS	TRANSPONDER	TRANSPONDER
5. REGULATORY ASPECTS FOR SIGNIFICANT PROTECTION	MANDATORY	VOLUNTARY	VOLUNTARY
6. STATUS	T&E COMPLETE	DEVELOPMENTAL	DEVELOPMENTAL
7. AVAILABILITY	1/80	12/81	10/84
8. WHEN PROTECTION ACTIVATED	MID-1980's	MID-1980's	LATE 1980's
9. UNIT COSTS	AC -- $6,300*	$18,000**	$40,000**
	GA -- $1,000*	$ 6,000** OR LESS (ESTIMATED) (OPTIONAL)	--
10. COST FOR PUBLIC PASSENGER SERVICE	$719M**	$326M**	$591M**

*ARINC RESEARCH ANALYSIS FOR ACAS (FAA-EM-76-2, DATED DECEMBER 1975) (1985 TRAFFIC NUMBERS)

**FAA ESTIMATES.

have no knowledge of relative bearing information on the threat targets. The Full BCAS has bearing information and can provide a situation type display of surrounding traffic. None of these systems can provide high quality CAS protection in dense terminal airspace since they do not have knowledge of aircraft or controller intent, terrain limitations, restricted airspace, etc. While the service offered by Full BCAS is substantially better than that of ACAS or Active BCAS, none of the three are easily site adaptable. It must be emphasized that even with this limitation the protection offered by BCAS is believed by the FAA and potential major users to be important and needed.

7.1.2 Service Area

Both the ACAS and BCAS system are "cooperative" systems, i.e., they require the installation of complementary equipment on all participating aircraft in order to receive protection. In the case of the ACAS system, the complementary element is another ACAS -- both boxes communicate with each other in the air-to-air mode in order to provide the needed protection. In the cases of BCAS, the cooperating element is another BCAS or the standard altitude reporting ATCRBS transponder (or later on any one of the possible future ATC transponders ATCRBS, DABS, or SAB). This difference is very critical since a BCAS equipped aircraft will receive immediate protection

against any other aircraft carrying an ATC transponder which, today, is implemented in all air carriers, most military, and about 30% the general aviation fleet. In contrast, the ACAS equipped aircraft receives no protection until others equip with ACAS and then, only those who obtain the equipment are protected from one another.

The ATCRBS transponder is already internationally standarized and is carried by military and international air carriers. Therefore, without any additional ICAO action, the BCAS equipped aircraft receives protection against international air carriers as well as those international aircraft carrying the ATCRBS transponder and altitude encoder. In contrast, ACAS would require ICAO standardization before international carriers would equip -- an unlikely prospect in the near term. Hence, BCAS has the clear advantage in this situation.

7.1.3 Display to Pilot

Neither ACAS nor Active BCAS, in its present form, has knowledge of the relative bearing position of the threat aircraft. Hence, only vertical maneuvers are available from these systems. Full BCAS will have bearing information available; hence both vertical and horizontal maneuvers are possible.

7.1.4 Cooperative Element

As discussed above in 7.1.2 the cooperative element in ACAS is another ACAS. In BCAS, the cooperating element is either BCAS or an altitude reporting transponder -- ATCRBS, DABS, or SAB. The transponder, in essence, becomes a multi-function device which is used as the central cooperating element in both the basic ATC system and also in the collision avoidance system.

7.1.5 Regulatory Impact

A key discriminator in this analysis is the regulatory impact of the technical alternatives. ACAS, being a dedicated, cooperative system requires substantial equipage before appreciable protection is achieved. BCAS, using the ATCRBS transponder, capitalizes on the large fleet equipage already achieved with ATCRBS transponders (which are now mandatory in all airspace above 12,500 feet and in selected terminal areas). Hence, the first user who equips will receive immediate protection against any aircraft flying above 12,500 feet as well as a substantial number of aircraft flying below that altitude. In contrast, the first user purchasing an ACAS receives no protection until others have also purchased the units.

In essence, the only practical approach for achieving substantial assurance of achieving ACAS protection is by mandatory fleet

equipage in a given time frame. In contrast, BCAS equipage can be allowed to continue on a voluntary basis with those users purchasing the equipment obtaining substantial protection for their investment.

7.1.6 Status

The development of ACAS is complete. Active BCAS has been experimentally flight tested and three models of the system are being fabricated by MIT Lincoln Laboratory--these models are expected to begin flight test in late-1979 with flight tests completed by mid-1980. A draft National Standard for the Active BCAS is being readied for issuance in December 1978, with a final Standard in mid-1980. Experimental flight tests of portions of the Full BCAS concept have been conducted and a system description has been completed. An RFP for the development of Full BCAS engineering models will be released in December 1978 (assuming OST approval of the revised BCAS AP soon to be forwarded). Allowing sufficient time for the development process, a National Standard for the Full BCAS should be available in mid-1983.

7.1.7 Availability and Initial Protection

These two items are interrelated and will be discussed together. The development of ACAS is essentially complete. However allowing the needed time for the issuing of additional standards, etc., and allowing time for manufacturing, substantial protection with ACAS could likely not be scheduled prior to mid-1980's even on a mandatory basis. While Active BCAS is behind ACAS in development, it enjoys the time leverage inherent in the wide transponder equipage which has already been achieved. Hence protection by either ACAS or Active BCAS could be achieved in a similar time frame. Neither system,

therefore, has time advantage in this respect. In contrast, Full BCAS will take additional time to develop and is behind the other two alternatives from the viewpoint of availability.

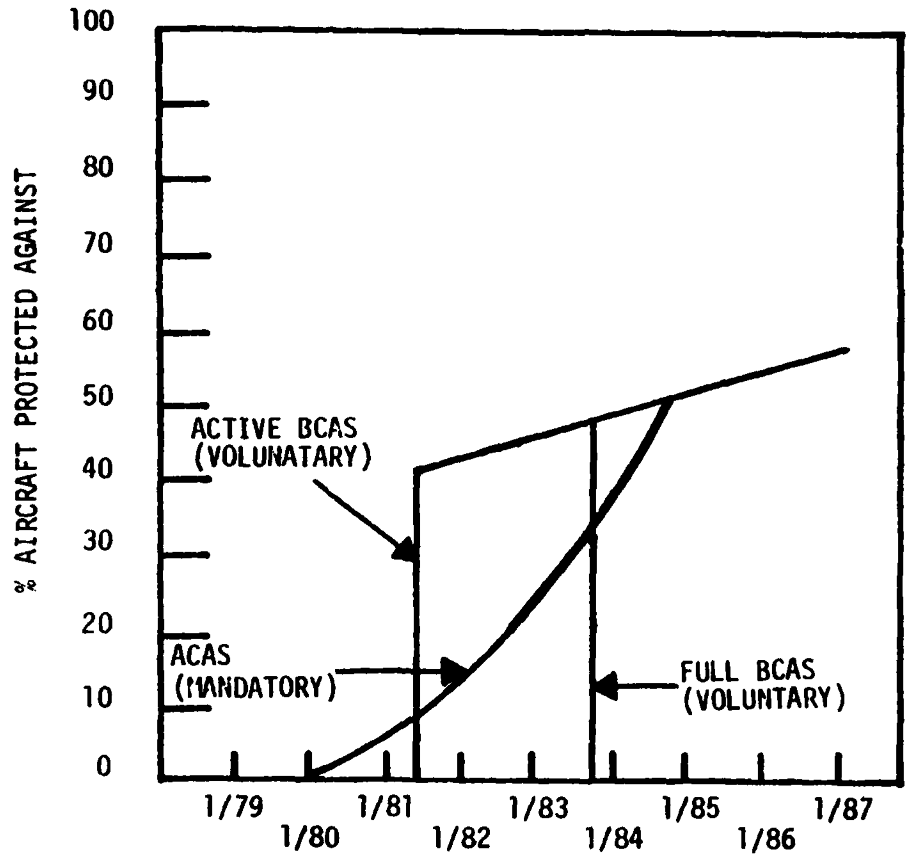
Figure 7-1 conceptually shows the protection that would be realized by any one aircraft at the time of installation of a ACAS or BCAS system. For example, the first aircraft equipped with ACAS does not receive any protection against any other aircraft in the fleet. As more and more aircraft gradually equip with ACAS the first aircraft receives more and more protection. In the case of BCAS, the first aircraft that equips immediately receives protection with respect to any aircraft already equipped with an altitude reporting transponder -- estimated at 40% of the fleet in the illustration at the time of the first Active BCAS installation. The protection of the first BCAS equipped aircraft increases as a function of increases in equipage with the ATC transponder and altitude encoders. Based on historical trends it can be expected that voluntary equipage with the altitude reporting transponder will gradually increase in time without being made mandatory. The curves shown are presented to illustrate conceptually what the trends would be.

7.1.8 Costs

The question of unit costs have been the subject of extensive analysis conducted by the FAA as well as for the FAA by independent

FIGURE 7-1

ACAS VS BCAS PROTECTION
(A CONCEPTUAL PORTRAYAL)



organizations. Detailed cost analysis were performed which indicated a unit cost of $6,300 for air carrier ACAS and $1,000 for general aviation ACAS[30], $18,000 for air carrier Active BCAS, and $40,000 for air carrier Full BCAS. Clearly, the unit cost of ACAS is much less than the projected unit cost for BCAS.

The first goal of the FAA in electing to implement either an ACAS or BCAS system would be to achieve protection of fare-paying passengers. With ACAS, full public passenger protection is not achieved until essentially all aircraft operating in controlled airspace are equipped with the ACAS system at an estimated life cycle fleet cost of $719M (for the Honeywell system and using 1985 fleet forecasts).(Table 7-2) However, with BCAS, public passenger protection requires only that air carrier and similar passenger carrying aircraft procure the BCAS unit while other aircraft (primarily general aviation) install only transponders and altitude encoders. Therefore, the life cycle cost of the BCAS service approximates $326M (including purchase of ATCRBS transponders and encoders for those aircraft not already equipped)for Active BCAS and $600M for Full BCAS. (Table 7-3). Hence, Active BCAS has a significant cost advantage in reaching the FAA objective or realizing additional protection to the users of public air transportation by capitalizing on the large amount of protection that is realizable by using the ATCRBS transponder as the cooperating element.

TABLE 7-2

ACAS AVIONICS LIFE CYCLE COSTS

AIRCRAFT CATEGORIES FOR SEPARATION ASSURANCE	FLEET SIZE 1985	% EXPECTED TO EQUIP	COST		
			HONEYWELL	MDEC	RCA
PUBLIC AIR TRANSPORTATION	4,900	100	$ 56M	$ 59M	$ 65M
FEDERAL AIR TRANSPORTATION	2,200	100	$ 22M	$ 24M	$ 24M
PRIVATE AIR TRANSPORTATION	6,000	100	$ 49M	$ 54M	$ 60M
OTHER FEDERAL AIRCRAFT	20,000	100	$229M	$244M	$254M
OTHER GENERAL AVIATION	189,400	100	$277M	$413M	$459M
AIRCRAFT WITHOUT AVIONICS	36,500	0	0	0	0
GROUND COSTS			0	3	0
RADAR ALTIMETER REMOVAL			86	86	86
TOTAL			$719M	$883M	$948M

NOTE: THESE COSTS INCLUDE ELECTRONICS, INSTALLATION, NONRECURRING COSTS, MAINTENANCE COSTS AND THE COST OF AN ENCODER

TABLE 7-3

BCAS AVIONICS LIFE CYCLE COSTS

AIRCRAFT CATEGORIES FOR SEPARATION ASSURANCE	FLEET SIZE 1985	% EXPECTED TO EQUIP	COST	
			ACTIVE	FULL
PUBLIC AIR TRANSPORTATION	4,900	100	$123M	$219M
FEDERAL AIR TRANSPORTATION	2,200	100	$ 56M	$100M
PRIVATE AIR TRANSPORTATION	6,000	100	$147M	$272M
OTHER FEDERAL AIRCRAFT	20,000	0	0	0
OTHER GENERAL AVIATION	189,400	0	0	0
AIRCRAFT WITHOUT AVIONICS	36,500	0	0	0
TOTAL	259,000		$326M	$591M

7.1.9 FAA Conclusions on ACAS and BCAS

The FAA has considered each of the above key points and factors in depth. They have been discussed at length with members of the user community and those responsible for ATC system operation. Detailed discussions have been held with Congressional interests as well as international interests. The selected approach was to defer the implementation of ACAS and proceed instead with the rapid development and implementation of Active BCAS initially while pursuing the development of Full BCAS for thóse users desiring the additional features that will be made available in this system.

The essential reasons for selection of BCAS were:

1. Significant service achieved with initial implementation with BCAS.

2. Lesser economic impact on those users not desiring the equipment.

3. Protection available in approximately the same time (Active BCAS compared to ACAS).

4. Lessen regulatory impact of BCAS.

5. Lessen ICAO impact.

6. Possibility of future BCAS system growth, enhancements, and evolution (which will be discussed later).

7.2 Active BCAS -- A Complementary System to ATARS

The FAA anticipates that obtaining high quality collision avoidance service in all environments will require that two systems be implemented -- ATARS plus Active BCAS. Both systems will build on the present ATCRBS or future DABS (or SAB transponder) as the cooperating element. ATARS will provide the back-up service when operating inside of ATC surveillance coverage and BCAS will provide back-up service when outside of surveillance coverage (i.e., oceanic airspace, low densities, etc.). Both systems are being designed to be mutually compatible so that they compliment one another. Thus BCAS is essentially as a system which complements ATARS, rather than being an alternative to ATARS.

7.3 "Full BCAS"

As discussed above, the Active BCAS is essentially a complementary system to ATARS -- ATARS providing high quality service within surveillance coverage and Active BCAS providing service in low-medium density areas outside surveillance coverage including oceanic areas.

The Full BCAS system offers the potential of providing three dimensional information on all ATCRBS equipped aircraft (as opposed to a two dimensional capability of the Active BCAS) and also providing improved service in high density areas. This improved service is anticipated to be significantly better than Active BCAS or ACAS, but still not as good as ATARS (since this BCAS would still be ignorant of local terrain data, aircraft intent information, airport configuration, etc.). However, it could provide the pilot with both a horizontal and vertical maneuver capability and possibly more important, with a "radar scope-type" presentation of his surrounding traffic. Like the Active BCAS, the cooperating element can be either another BCAS or an altitude reporting ATCRBS, DABS, or SAB transponder.

The FAA anticipates that this full BCAS will take several years of development to mature and will likely be expensive, $40,000 - 65,000 per unit -- this in turn will certainly limit its application to larger aircraft. Nevertheless, because of its significant potential for improved services and to provide some interim protection in those areas which the ATARS capability is not yet implemented (because of long procurement, budgeting and installation lead times) the FAA expects to pursue the development of this system (as discussed at the recent TSARC review and presented in the BCAS Acquisition Paper).

7.4 The Remaining Alternatives

As a result of considerations outlined herein, and the selection of BCAS instead of ACAS, the remaining alternatives can be reduced essentially to the two shown in Table 7-4.

TABLE 7-4

THE FINAL ALTERNATIVES

SURVEILLANCE	DATA LINK	SEPARATION ASSURANCE	
		DENSE AIRSPACE	OUTSIDE ATC
SELECTIVE ADDRESS BEACON DABS	VHF (NEW) DABS	ATARS	BCAS

<u>ALTERNATIVES POSSIBLE WITH REMAINING ELEMENTS</u>

1. SAB + VHF D/L + ATARS + BCAS
2. DABS + ATARS + BCAS

8. THE TWO MAIN ALTERNATIVES

The preceding section presented the rationale for limiting the detailed examination of alternative approaches of improving the three functions of beacon surveillance, air-ground communications, and aircraft separation assurance to just two main alternatives -- DABS + ATARS + BCAS and SAB (4096) + VHF D/L + ATARS + BCAS. Both of those alternatives appear to provide a significantly improved beacon-based surveillance capability that could be used to support advanced automation features, including ATARS. Both could provide improved air ground communications via a data link that would support advanced automation features which depend on the automatic generation and transmission of ATC messages. Both could provide improved aircraft separation assurance through the use of ATARS. The fundamental difference between the two alternatives is that:

1. DABS integrates the functions of surveillance and data link communications within a single basic design.

2. SAB (4096) + VHF D/L would provide separate designs for the functions of surveillance and data link communications and would provide a maximum flexibility in implementing those two functions.

The DABS based alternative and the SAB (4096) based alternative are described briefly in Sections 8.1 and 8.2.

8.1 The DABS Alternative

The DABS concept was initially conceived in the early 1970's as the most cost effective approach of responding to the need to:

- o Upgrade ATCRBS to include a discrete address mode, and
- o Automate and make more precise air traffic advisory service by using the improved surveillance in conjunction with data processing on the ground and an air-ground data link.

8.1.1 DABS

The most complete reference that describes the DABS part of the DABS/ATARS alternative is an FAA Report titled "DABS: A System Description."[32] Although that document was published in November 1974, it is still representative of the DABS system subsequently developed by Texas Instruments under an FAA contract. The first model of that system has been delivered to the FAA and is currently being tested by the FAA at NAFEC. The abstract of the referenced document provides a good summary description of DABS as follows.

"The Discrete Address Beacon System (DABS) is a cooperative surveillance and communication system for air traffic control. It employs ground-based sensors (interrogators) and airborne transponders. Ground-to-air and air-to-ground data-link communications are accommodated integrally with the surveillance interrogations and replies. DABS has been designed as an evolutionary replacement for the current Air Traffic Control Radar Beacon System (ATCRBS) to provide the enhanced surveillance and communication capability required for air traffic control in the 1980s and 1990s. Compatibility with ATCRBS has been emphasized to permit an extended, economical transition.

A principal feature of DABS is that each aircraft is assigned a unique address code. Using this unique code, interrogations can be directed to a particular aircraft, and replies unambiguously identified. Channel interference is minimized because a sensor can limit its interrogation to targets of interest. In addition, by proper timing of interrogations, replies from closely-spaced aircraft can be received without mutual interference. The unique address in each interrogation and reply also permits the inclusion of data-link messages to or from a particular aircraft. DABS uses the same frequencies for

interrogations and replies as ATCRBS (1030 and 1090 MHz, respectively). The DABS interrogation is transmitted using DPSK at a 4 Mbps rate, and comprises 56 or 112 bits including the 24-bit discrete address. The reply also comprises 56 or 112 bits including address, and is transmitted at 1 Mbps using binary pulse-position modulation. Coding is used on both interrogations and replies to protect against errors.

The DABS sensor provides surveillance of DABS- and ATCRBS-equipped aircraft, and data-link service to DABS aircraft. In addition, it performs radar/beacon correlation of radar target reports from a collocated radar. The DABS sensor transmits surveillance data to, and exchanges messages with, air traffic control facilities (TRACONs and ARTCCs) via low-rate digital circuits. The DABS sensor communicates directly with adjacent DABS sensors to hand off targets and to provide surveillance and communication backup in the event of momentary link failures.

The DABS transponder replies to both ATCRBS and DABS interrogations, and interfaces with a variety of data-link message display and input devices. The rms surveillance accuracy provided by DABS is the order of 100 ft and 0.1° in range and azimuth, respectively. Surveillance and data-link

communication capacities exceed by a substantial margin projected ATC requirements through the remainder of this century."

8.1.2 ATARS System Description

ATARS is an automatic traffic advisory and conflict resolution service provided by a totally automated, site adpated, ground computer system which operates independently from the ATC computers. It is an outgrowth of the IPC concept which was described and recommended for development by the Air Traffic Control Advisory Committed (ATCAC) in 1969.[31]

Aircraft Separation Assurance is achieved by continuously providing pilots with traffic advisory information on the location of proximate and threatening aircraft and by issuing resolution advisories on an as needed basis. In this way the safety of civil air traffic is preserved while maintaining freedom of flight for the VFR community to the maximum extent possible.

ATARS services can be provided to all aircraft, controlled and uncontrolled in both the en route and terminal environment. For those equipped for ATARS services, protection is provided against all aircraft that are equipped with altitude reporting transponders. To receive ATARS service, an aircraft must carry a DABS transponder with an encoding altimeter and an ATARS display or alternatively a SAB

transponder plus a VHF data link plus an ATARS display. The ground portion of the ATARS system consists of the DABS or SAB sensor which provides surveillance information and, on a DABS or VHF data link, acts as a communications link to the aircraft; a site adapted computer which is independent of the ATC computer system, and has knowledge of surrounding airspace, terrain, ATC procedures, etc.; and interfaces to the ATC facilities serving the airspace covered by the surveillance sensor.

Aircraft equipped for ATARS service will receive traffic advisories on aircraft that are determined by the algorithm to be proximate or a threat. Proximate aircraft information will be displayed to the pilot to alert him concerning the presence of the nearby aircraft and to aid him in visual acquisition. When an aircraft poses a threat, the traffic advisory service will declare it as a potential threat and display additional information to aid the pilot in threat assessment in addition to visual acquisition. The threat data should enable the pilot to evaluate the potential threat and to avoid maneuvers which would aggravate the situation. If the aircraft separation continues to narrow such that the projected miss distance is less than the established threshold for that region of airspace, then one or both of the aircraft will receive a resolution message at a predetermined time (currently 30 seconds) before the estimated time to closest approach. The resolution message will be compatible with the threat data provided in the traffic advisory.

Although ATARS will provide similar traffic advisory and resolution service to both controlled and uncontrolled aircraft, the manner in which it will be utilized by the pilot is expected to differ depending on the aircraft's control status. Since the pilot of the uncontrolled aircraft relies on see-and-avoid techniques as the principal method of maintaining separation, it is anticipated that he would utilize the traffic advisory data to visually acquire aircraft of concern and to determine whether or not they represent a potential threat. Once the aircraft is visually acquired, the pilot could then mentally integrate the traffic advisory data with other factors to determine whether or not evasive action need be taken. Although a goal of the traffic advisory service is to provide the pilot with sufficient information to enable him to maintain adequate separation in the absence of visual acquisition, the pilot may choose to delay evasive action until receipt of a resolution message if the threat aircraft is not visually acquired. In this way the traffic advisory service would provide increased air safety by reducing the potential for mid-air collisions which may result from undetected traffic or optical illusions without imposing constraints on the pilot. The basic premise is that once the VFR pilot is made aware of a potential encounter and provided data concerning the threatening aircraft, the pilot can maintain adequate separation on his own.

In order to minimize pilot work load and ATC interaction, it is anticipated that controlled aircraft will rely more heavily on

resolution messages rather than on the traffic advisories for determining the maneuver needed to resolve potential conflicts. In these cases the traffic advisories would serve as a means for alerting the pilot to the details of the potential conflict and would prepare the pilot for the possibility of an escape maneuver if the conflict situation persists or worsens. Alerting the pilot to the specifics of the potential conflict would also serve to discourage independent maneuvers on the part of the pilot which could aggravate the situation.

For example, ATARS has a communication link to the ATC computers and will interface with the Conflict Alert function. Whenever a threat advisory is issued to a controlled aircraft, an ATARS Threat Notice message, which identifies the pair of aircraft in potential conflict, is sent to ATC facility responsible for the aircraft. This threat notice may or may not result in an alert being generated for the responsible controller(s) depending on the status of the Conflict Alert/Conflict Resolution function. The resolution notice message will identify the aircraft involved and the resolution maneuver issued to each. Upon receipt, the ATC computer system will compare the data to the present status of the Conflict Alert/Conflict Resolution function and display appropriate information to the responsible controllers.

8.1.3 Integration of Functions

In the current DABS design, the functions of surveillance and data link are fully integrated in both the ground equipment and in the avionics. The function of aircraft separation assurance (ATARS) can be procured and implemented as an add-on to either the ground DABS equipment or the airborne DABS transponders or, in the case of avionics, as an integrated unit. The system is however being designed with the expectation that DABS + ATARS will normally both be installed at the ground surveillance site and that DABS + ATARS will constitute a normal complement of avionics -- except for perhaps a small part of the G.A. and military aircraft that either do not have a transponder at all or where the owner judges that continued use of ATCRBS is satisfactory for his purposes.

The DABS transponder would be sufficiently different from the ATCRBS transponders that modification of existing transponders to achieve the DABS capability is not likely. Hence, any aircraft wanting the DABS capability would replace the existing transponder with a DABS transponder.

8.2 SAB (4096) + VHF D/L + ATARS

The most comprehensive description of this alternative is contained in a FAA report of April 1974 on a "Study of Alternative Beacon Based Surveillance and Data Link Systems."[27] During the formulation of

that report the FAA in conjunction with representatives of various user groups and The MITRE Corporation reached agreement as to the general design characteristics that such a system should have if it was to provide services similar, but not equal, to those provided for in the DABS design. That alternative called for an upgrading of the ATCRBS surveillance systems to include the SAB capability, providing surveillance data from SAB to separate ATARS processors dedicated to the aircraft separation function, and the transmission of the ATARS messages and other ATC messages via a separate VHF data link.

8.2.1 SAB (4096)

The term Selective Address Beacon (SAB) system is used to refer to an ATCRBS based system that has the added capability of selectively addressing individual aircraft. SAB is solely a surveillance system and must be used in conjunction with either a voice or data link communication system for the transmission of ATC messages. The easiest and least expensive way to implement selective addressing is to interrogate aircraft by using the same 4096 identity code and modulation now used in the ATCRBS replies. The addition of the selective addressing feature provides a significant improvement not

otherwise attainable in the basic ATCRBS -- the elimination of the overlap of messages from aircraft in close proximity (synchronous garble).

One of the major differences between SAB (4096) and DABS is the method of entry and addressing. When a SAB (4096) equipped aircraft first enters the system, the aircraft's code and its VHF data link address must be associated at the ATC facility. This is done automatically in the DABS system but has to be done procedurally in the SAB (4096) system. One way to achieve the addressing capability would be to have the pilot to set his 4096 code and VHF channel when the aircraft first enters the ATC system to receive ATC services. In the case of VFR aircraft that do not take the initiative to enter the system, the ATC system may not be able to to establish communications or provide ATC or ATARS services to such aircraft even if the controller or the automated system saw a need for such communications. (ATCRBS could be used operationally in the same way as SAB but would not provide for the elimination of synchronous garble as a potential problem.)

A SAB ground site differs in a few ways from the Improved ATCRBS ground site. Each SAB aircraft must be continually tracked at the

surveillance site so it can be interrogated when the ground antenna is pointing at the aircraft. The site must also determine an appropriate "roll call" so that addressed interrogations and replies do not overlap. Aircraft must be reinterrogated if their replies are missing or corrupted by interference. A tracking capability would provide position forecast information for this purpose but the number of interrogations per discrete address must be limited, if reasonable capacities are to be expected. A monopulse tracking capability to deduce a target's azimuth from a single reply is included in the SAB design to improve ATCRBS performance, reduce the interference problem and provide the needed capacity for SAB + ATARS operation.

The SAB (4096) airborne transponder is an extension of the ATCRBS transponder. Changes to the internal suppression logic and address recognition must be provided. Responses to ATCRBS identity and altitude interrogations remain unchanged. It was the assessment of the ARINC Research Corporation[8] that a SAB adapter could be used in conjunction with existing ATCRBS transponders on high performance aircraft already equipped with the higher quality ATCRBS transponders but that replacement of ATCRBS by SAB transponders would be the practice for lower performance aircraft already equipped with ATCRBS transponders.

8.2.2 VHF Data Link

The major objectives in the design of the VHF data link were to allow the use of VHF transceivers wherever possible; provide the capacity to handle future ATC message requirements; and provide the operational features compatible with the use of the data link for providing the ATARS aircraft separation assurance. Thus the concept described here called for the development of new VHF D/L ground sites to be colocated with the beacon surveillance sites where needed and to achieve the airborne capacity through the use of VHF transceivers such as those now used for voice communications.

The design of the ground station is described in the FAA DABS alternatives study of April 1974.(27) It includes provisions for bit rates of 4800 bits per second and automatic tuning of the avionics by a ground data link command.

The specific avionics design used herein for costing purposes was developed by The ARINC Research Corporation.(7) The avionics design was based on the concept presented in the earlier DABS alternatives study(27) but uses ARINC's experience in providing data link services to the airlines for company traffic as the basis for the actual design. The VHF D/L would be realized in high performance aircraft by using a data link modem, an auto tune

capability, and appropriate controls in conjunction with a basic VHF transceiver such as those used today for voice communications. A similar capability without the auto-tune capability was presented by ARINC for aircraft not equipped with remote controls. The lack of the auto-tune capability on some aircraft would increase the workload of both the pilot and controller. Further, the ATARS function could be negated if the proper channel is not selected by the pilot.

8.2.3 ATARS

The ATARS functions to be performed on the ground and in the aircraft would be the same as previously discussed. Implementing ATARS as a completely separate function rather than as an integrated part of DABS would result in a small increase in the cost of ground equipment.

9. COST COMPARISON

One of the major factors in selecting the preferred alternative is, of course, the costs -- costs to the FAA, cost to commercial air carriers, costs to the various segments of general aviation, costs to the military, and total costs. The following Section 9.1 presents the unit costs of the avionics and total incremental equipment acquisition costs based on assumptions as to aircraft equipage. Section 9.2 presents the unit cost of the ground equipment and total incremental equipment costs using two hypothetical implementation scenarios to illustrate the comparative costs of two different levels of implementation. Total comparative costs are shown in Section 9.3. A more detailed analysis of the cost estimates is contained in Appendix A.

COST BIAS: THIS ANALYSIS IS HEAVILY WEIGHTED IN FAVOR OF THE SAB + VHF D/L ALTERNATIVE. FOR EXAMPLE, AVIONICS INSTALLATION COSTS ARE NOT INCLUDED. THE EXTRA COSTS ASSOCIATED WITH THE INSTALLATION OF TWO EQUIPMENTS, THE SAB TRANSPONDER AND THE VHF DATA LINK MODEM INSTEAD OF JUST THE ONE DABS TRANSPONDER, IS IGNORED. IT IS ESTIMATED THAT THOSE ADDITIONAL COSTS WOULD EASILY EXCEED $200M, WHICH IS DIRECTLY ADDITIVE TO THE SAB + VHF ALTERNATIVE. FURTHERMORE, IT IS ASSUMED THAT ALL VHF TRANSCEIVERS IN AIR CARRIERS, CORPORATE JET, TWIN ENGINE GENERAL AVIATION, AND A LARGE PART OF THE SINGLE ENGINE GENERAL AVIATION AIRCRAFT WOULD BE ABLE TO ACCOMMODATE

THE VHF DATA LINK WITHOUT REPLACEMENT. IT IS KNOWN THAT THIS IS AN OVERLY OPTIMISTIC ASSESSMENT OF THE QUALITY OF VHF TRANSCEIVERS CURRENTLY IN USE AND THAT AN ACCURATE ASSESSMENT WOULD SIGNIFICANTLY RAISE THE COST OF THE SAB ALTERNATIVE. SIMILAR BIASING ASSUMPTIONS ARE MADE IN FAVOR OF SAB + VHF IN COSTING THE GROUND SYSTEM.

9.1 Avionics Costs

All estimates of avionic costs were taken from independent studies conducted by The ARINC Research Corporation.[6,7,8,9] BCAS costs are not included since they would be common to both alternatives.

9.1.1 Avionics -- Unit Costs

There are three ways of looking at the unit costs of the avionics: (1) the price of the individual components, (2) the package costs per type of user aircraft, and (3) the incremental costs of obtaining improved service to users who in the absence of SAB or DABS would elect to equip his aircraft with one or more ATCRBS transponder and one or more VHF transceiver. Those three views are reflected in Tables 9-1, 9-2, 9-3, and 9-4 respectively.

In developing the cost estimates, The ARINC Corporation considered two classes of avionics -- one class for air carriers and high performance general aviation aircraft and one class for lower

TABLE 9-1

AVIONICS SELLING PRICE PER UNIT

(1976 $)

	AIR CARRIER	HIGH PERFORMANCE GA	MEDIUM AND LOW PERFORMANCE GA
DABS/ATARS			
Transponder (LSI)	5212	6776	1352*
Transponder (Discrete)	6625	8612	1082
Control Box	516	516	Included
ATARS Display**	2198	2857	1110
Antenna	63	75	13
SAB (4096)			
Transponder	4176	5429	784
Control	516	516	Included
Antenna	63	75	13
SAB Adapter	1201	1561	N/A
ATCRBS			
Transponder	3975	5169	612
Control	516	516	Included
Antenna	63	75	13
VHF D/L + ATARS			
Transceiver	2500	3250	1254
Control Box	516	516	Included
Data Modem**	2845	3699	1240
ATARS Display**	2198	2857	1114
Auto-tune	299	389	N/A***
Antenna	180	240	16

*Includes ATARS display as part of integral transponder/display unit.

**Based on discrete technology. LSI technology version should have lower costs.

***Not available in low cost avionics.

TABLE 9-2

AVIONIC PACKAGE COSTS

(LESS ENCODING ALTIMETER, ATC DISPLAY AND INSTALLATION COSTS)

(1976 $)

	AIR CARRIERS (DUAL)	HIGH PERFORMANCE GA	MEDIUM AND LOW PERFORMANCE GA
SAB + VHF D/L + ATARS (VHF TRANSCEIVERS USABLE)	20,194	12,965	3,151
SAB + VHF D/L + ATARS (ADD ONE TRANSCEIVER)	23,390		4,421
DABS + ATARS	15,978 (LSI--DABS) 18,804 (DISCRETE)	10,224 (LSI--DABS) 12,060 (DISCRETE)	1,365 (LSI--DABS AND ATARS) 2,205 (DISCRETE)

- DISCRETE COMPONENT TECHNOLOGY USED IN ALL CASES EXCEPT DABS TRANSPONDER AS NOTED.
- ALL SAB COSTS ARE FOR SAB (4096)

TABLE 9-3

INCREMENTAL EQUIPMENT COSTS OF ACHIEVING IMPROVED PERFORMANCE
(1976 DOLLARS)

NEW AIRCRAFT

USER CLASS	DABS SCENARIO		SAB SCENARIO	
	ADDITIONAL EQUIPMENT	ADDED COSTS	ADDITIONAL EQUIPMENT	ADDED COSTS
AIR CARRIER	2(Δ DABS + ATARS)	6,870 (LSI) 9,696 (DISCRETE)	2(Δ SAB + ATARS + DATA MODEM + AUTO TUNE)	11,036
HIGH PERF. GEN. AV.	1(Δ DABS + ATARS)	4,464 (LSI) 6,300 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM + AUTO TUNE)	7,205
MEDIUM PERF. GEN. AV.	1(Δ DABS + ATARS)	740 (LSI) 1,580 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM)	2,526
LOW PERF. GEN AV.	1(Δ DABS + ATARS)	740 (LSI) 1,580 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM)	2,526
	1(DABS + ATARS)	1,365 (LSI) 2,205 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM + VHF TRANS. W ANT.)	3,796
	1(Δ DABS + ATARS + VHF TRANS. W ANT.)	2,010 (LSI) 2,850 (DISCRETE)	1(SAB + ATARS + DATA MODEM + VHF TRANS. W ANT.)	4,421

Δ = INCREMENTAL COST OVER ATCRBS TRANSPONDER

TABLE 9-4

INCREMENTAL EQUIPMENT COSTS OF ACHIEVING IMPROVED PERFORMANCE
(1976 DOLLARS)

EXISTING AIRCRAFT

USER CLASS	DABS SCENARIO		SAB SCENARIO	
	ADDITIONAL EQUIPMENT	ADDED COSTS	ADDITIONAL EQUIPMENT	ADDED COSTS
AIR CARRIER	2(Δ DABS + ATARS)	6,870 (LSI) 9,696 (DISCRETE)	2(Δ SAB + ATARS + DATA MODEM + AUTO TUNE + CONTROL BOX)	12,118
	2(Δ DABS + ATARS) + VALUE OF EXISTING ATCRBS TRANSPONDER*	10,845 (LSI) 13,671 (DISCRETE)	2(SAB ADAPTER + ATARS + DATA MODEM + AUTO TUNE + CONTROL BOX)	14,118
HIGH PERFORMANCE GENERAL AVIATION	1(Δ DABS + ATARS)	4,464 (LSI) 6,300 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM + AUTO TUNE + CONTROL BOX)	7,721
	1(Δ DABS + ATARS) + VALUE OF EXISTING ATCRBS TRANSPONDER*	7,049 (LSI) 8,885 (DISCRETE)	1(SAB ADAPTER + ATARS + DATA MODEM + AUTO TUNE + CONTROL BOX)	9,022
MEDIUM PERFORMANCE GENERAL AVIATION	1(Δ DABS + ATARS)	740 (LSI) 1,580 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM)	2,526
LOW PERFORMANCE GENERAL AVIATION	1(Δ DABS + ATARS)	740 (LSI) 1,580 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM)	2,526
			1(Δ SAB + ATARS + DATA MODEM + VHF TRANS. W ANT.)	3,796

Δ = INCREMENTAL COST OVER ATCRBS TRANSPONDER

* ASSUMED TO BE 50% OF THE ORIGINAL VALUE BASED ON HALF THE EXPECTED LIFE ON AN AVERAGE.

performance general aviation aircraft. Based on its observations of the general practice in the selling price of the avionics, ARINC assumed that the cost of the equipment purchased for high performance aircraft would be 30% greater than the price the air carriers would pay when purchasing in large lots. The list price of the low performance avionics was estimated by ARINC to be the factory selling price plus a 100% mark up by the distributor.

It will be noted that Tables 9-1, 9-2, and 9-3 list one cost for a DABS transponder produced using LSI technology and a second cost for the same transponder produced using discrete component technology. All costs for the SAB and VHF data link components are based on the use of discrete component technology. Therefore, the DABS costs based on discrete technology should be used for comparison purposes. The DABS LSI costs should be viewed as the more likely costs of DABS if industry elects to apply that technology.

It will also be noted that the costs of encoding altimeters and ATC displays are not included in the tables. Those costs are not shown since those costs would be the same in both alternatives and need not be considered for comparative purposes.

Two "package" costs are shown in Table 9-2 for the SAB based alternative. The lower cost applies to the cases where the user

elects to use a VHF transceiver for use with the VHF D/L that he would have purchased for other reasons. The higher cost applies to the cases where the user elects to buy an additional transceiver. For example, air carriers who normally carry 3 VHF transceivers may elect to use one of those for data link while an air carrier who normally carries only two transceivers may elect to procure a third one for the data link.

Table 9-3 portrays the incremental costs that would be incurred by the purchaser of a new aircraft to achieve the improved services over and above what would be possible through the continued use of ATCRBS and voice communications. For example, the purchaser of a single engine low performance GA aircraft who would have purchased a single ATCRBS transponder would have to pay an additional $740 to obtain a DABS transponder with an ATARS display produced with LSI technology or $1580 if manufacturers elect to use discrete component technology. The cost of achieving the SAB + VHF D/L + ATARS capability would be $2,526 for those who would have purchased 2 VHF transceivers anyway and elected to use one for data link or $3,796 for those that would have to buy an additional transceiver.

The situation is somewhat more complex for aircraft that were in the inventory at the beginning of the transition period as shown in Table 9-4. Of particular interest is the case where the existing

transponder has a long enough remaining life to consider achieving the SAB capability by buying an adapter rather than a new SAB transponder. Under the SAB scenario, it has been assumed that 50% of the air carrier and high performance GA aircraft would elect to purchase the adapter. To keep the DABS scenario compatible with this assumption, it was assumed that the average value of the ATCRBS transponders in those same aircraft would be 50% of the cost of a new ATCRBS transponder and chargeable to the delta DABS costs. Thus, as shown in Table 9-4, the delta cost for air carriers would be $14,118 for SAB vs $13,671 for DABS. For the high performance GA, the corresponding numbers are $9,022 for SAB and $8,885 for DABS. The allowance for this equipage was fully considered in deriving the total comparative costs of the two alternatives.

9.1.2 Avionics - Acquisition Ground Rules and Assumptions

Avionics total costs for acquisition of equipment during a ten year transition period were estimated using the following ground rules and assumptions.

- 10 year transition: 1984-1993

- Four classes of civilian aircraft would equip as follows:

- Air Carriers would equip with redundant ATARS related equipment and, in the case of the SAB based alternative, the air carriers would obtain the VHF D/L capability by using a VHF transceiver purchased for other purposes.

- High Performance GA (all turbine powered plus 10% of other multiple engine GA aircraft) would equip with single thread ARINC quality equipment. VHF transceivers purchased for other purposes would be used to obtain the VHF D/L capability.

- Medium Performance GA (the balance of the other multiple engine GA aircraft) would equip like the High Performance GA but would use the low cost avionics.

- Low Performance GA (all single engine) would equip with single thread low cost equipment. Those having two VHF transceivers for other purposes would use one to get the VHF D/L capability. Those that would only have had a single VHF transceiver but desiring the ATARS capability via the VHF D/L alternative would buy a second transceiver whose costs are chargeable to the SAB + VHF D/L + ATARS alternative.

- <u>Military Aircraft:</u> The costs of installing DABS/ATARS equipment in military aircraft have been estimated by the FAA and reported on in earlier documents.[2,3] No estimates have been made by the military for the SAB based alternative. For the purposes of this document, it was judged that it would be obvious that the cost of designing ground and airborne components of the SAB alternative and installing the equipment in military aircraft would be substantially greater than the DABS based alternative. This is because the DABS based alternative basically requires the replacement of ATCRBS transponders with DABS transponders plus a display while the SAB alternative would require modifications or replacement of the ATCRBS transponder, plus a display plus a data modem as a minimum with other changes to the military UHF/VHF transceivers also likely. This point will be addressed in more detail in Section 10.

- Assume that all new aircraft procured during the transition period include the DABS or SAB based avionics.

- Assume that aircraft in the inventory at the beginning of the transition period that are scheduled to equip by the end of the period do so through the purchase of new equipment to replace ATCRBS equipment that has no residual value. (Any

residual value would be equally applicable to both alternatives and would not affect cost differentials.) One exception to this ground rule is that in the case of the SAB based alternative, 50% of the air carriers and high performance aircraft would elect to modify existing ATCRBS transponders to realize the SAB capability.

- Comparative costs to be based on equipment costs only, since O&M costs would be a percentage of procurement costs and would not impact on the identification of the least costly alternative. Installation costs are not included since ARINC cost estimates were not available on all options. As in the case of military aircraft, installation costs of the SAB + VHF D/L + ATARS in civil aviation aircraft was judged to be more expensive than DABS/ATARS because of the larger number of components that would be involved in the SAB based alternatives. Thus, installation costs differences would merely add to the cost differential in favor of DABS.

- FAA forecasts for civilian aviation composition and size would be used with extrapolations for those years beyond the FAA forecasts.

- As an upper limit, it was assumed that 100% of the air carriers, 100% of the high performance GA, 100% of the

medium performance GA and 70% of the low performance GA might equip by 1994 due to the services that would be provided. But, differential costs would be shown so the reader could judge what the cost differentials would be at lower levels of equipage.

- Avionic costs to be shown are delta costs over and above the costs that the users would have incurred if they had procured only the normal number of VHF transceivers and had continued to buy new ATCRBS transponders or replace old ATCRBS transponders with new transponders.

9.1.3 Avionics -- Total Costs

Table 9-5 presents the total differential avionics equipment costs for four classes of civilian aircraft for the DABS + ATARS and the SAB (4096) + VHF D/L + ATARS where production is based on discrete component technology and for DABS + ATARS where the DABS transponder is produced using LSI technology.

9.2 Ground Equipment Costs

All estimates of ground equipment costs were prepared by personnel with a direct knowledge of the DABS and ATARS designs and with knowledge of the latest projections of the expected production costs of those designs. Estimates of the SAB (4096) and VHF D/L systems were made by the same personnal using the designs described in the 1974 DABS Alternatives Study.

TABLE 9-5

TOTAL DIFFERENTIAL* AVIONICS COSTS

($\$ \times 10^6$)

	A/C			HIGH GA			MEDIUM GA			LOW GA		
	NEW	RETRO	TOTAL	NEW	RETRO	TOTAL	NEW	RETRO	TOTAL	NEW	RETRO	TOTAL
DABS + ATARS (LSI) GRAND TOTAL: 311	6.389	22.434	28.823	43.747	54.111	97.858	12.950	17.390	30.340	73.305	81.067	154.372
DABS + ATARS (DISCRETE) GRAND TOTAL: 546	9.017	29.592	38.609	61.740	71.370	133.110	27.650	37.130	64.780	136.338	173.089	309.427
SAB + D/L + ATARS GRAND TOTAL: 938	10.310	33.227	43.537	70.609	78.692	149.301	44.205	59.361	103.566	254.977	386.039	641.016

*DIFFERENTIAL IS TAKEN OVER AN ATCRBS SCENARIO ASSUMED TO EXIST IN THE ABSENCE OF DABS OR SAB.

9.2.1 Ground Sites -- Unit Costs

In costing the ground equipment, the assumption was made that new ATCRBS antennas would be implemented at the terminal sites prior to the implementation of either DABS or SAB. It was assumed that the antennas at the en route sites would have to be improved at an average cost of $90K each, in order to support the basic surveillance improvements including monopulse detection and that an additional $60K each would be required to provide back-to-back antennas to increase the data rate at en route sites providing ATARS service. It was also assumed that certain costs would be incurred in upgrading ATCRBS sites prior to the implementation period. Based on those assumptions, the estimates of the average costs of achieving the new capabilities are shown in Table 9-6.

9.2.2 Ground Equipment -- Hypothetical Implementation Scenarios

Two hypothetical scenarios were developed to examine comparative costs of the two alternatives at two different levels of deployment. They are described in more detail in Appendix A. THESE SCENARIOS WERE DEVELOPED ONLY AS STRAWMEN FOR COMPARISON PURPOSES. THEY DO NOT REPRESENT CURRENT FAA POLICY ON IMPLEMENTATION. SEPARATE ACTION IS CURRENTLY UNDERWAY TO DEFINE THE PLAN TO BE FOLLOWED WHEN DABS IS IMPLEMENTED.

TABLE 9-6

INCREMENTAL COSTS* OF NEW CAPABILITIES
AT ATCRBS GROUND SITES
(1976 $)

CAPABILITY	COST PER FACILITY -- $ IN THOUSANDS		
	TERMINAL SITES		EN ROUTE SITES
	400 A/C	700 A/C	
ATCRBS**	199	219	289
ATCRBS + MONOPULSE DETECTION	590	650	680
SAB (4096)	700	760	790
VHF D/L	198	324	198
ATARS (NON DABS)	143	203	293
SAB (4096) + VHF D/L + ATARS	1041	1287	1281
DABS + ATARS	950	1052	1100
DABS WITHOUT ATARS	NOT USED	NOT USED	920***

SOURCE: FAA, AUGUST 1978

*COSTS INCLUDE INSTALLATION AND INITIAL SPARES

**UPGRADING COSTS BETWEEN NOW AND START OF IMPLEMENTATION OF DABS OR SAB BUT DOES NOT INCLUDE FUNDS FOR ANY IMPROVEMENTS OR REPLACEMENT OF EN ROUTE ANTENNAS.

***DABS + ATARS ($1100K) MINUS $100K FOR ATARS PROCESSORS AND $20K ALLOWANCE FOR INITIAL SPARES AND INSTALLATION AND $60K FOR DELETION OF BACK-TO-BACK ANTENNA.

9.2.2.1 Scenario 1: Minimum Deployment

The following are the major features of this scenario:

- Data link would be installed at all en route surveillance sites and at all terminal sites with ARTS-III to achieve increased controller productivity via advanced automation which automatically generates ATC messages and transmits the messages to and from aircraft via a data link.

- A selective or discrete addressing capability would be provided at only 21 high density areas (ten of which have two surveillance sites) to provide surveillance that is free of synchronous garble problems. ATCRBS with monopulse detection would be implemented at other sites scheduled to receive ATARS. Standard ATCRBS would continue to be used at the remaining sites.

- ATARS would be implemented at just the terminal sites (73) serving ARTS-III facilities to provide increased aircraft separation assurance both inside TCA/TRSA airspace and outside the TCA/TRSA airspace but within coverage of the surveillance site. Additional protection to larger passenger aircraft would be realized in low density airspace via BCAS.

Under this Scenario I, the equipment complement for the two alternatives would be as shown in Table 9-7.

9.2.2.2 Scenario II: Maximize Single Site Coverage for ATARS

The deployment under Scenario I would be expanded as follows:

- ATARS would be implemented at all terminal surveillance sites to provide maximum aircraft separation services in the terminal areas where most midair and near midair collisions occur.

- ATARS would also be implemented at as many en route sites as necessary (50) to maximize single site ATARS coverage. ATARS would not be implemented at en route surveillance sites where surveillance coverage is obtainable from the terminal sites.

Under this Scenario II, the equipment complement for the two alternatives would be as shown in Table 9-8. Two options are shown for the SAB based alternative. Option 1 provides for the selective addressing capability at just the 31 terminal surveillance sites serving the 21 highest density areas. Option 2 provides for selective addressing at all sites receiving the ATARS capability to preclude synchronous garble even in the lower density airspace from interfering with the collision avoidance service of ATARS.

TABLE 9-7

EQUIPMENT COMPLEMENT AT GROUND SITES FOR SCENARIO I
UNDER A SAB OR DABS ALTERNATIVE

	TYPE OF FACILITY	SAB ALTERNATIVE		DABS ALTERNATIVE
		OPTION I	OPTION II	
TERMINAL	31 HIGH DENSITY ARTS III TERMINAL SITES*	SAB + VHF D/L + ATARS*	SAB + VHF D/L + ATARS*	DABS + ATARS*
TERMINAL	42 OTHER ARTS III TERMINAL SITES	ATCRBS + MONO-PULSE + VHF D/L + ATARS	SAB + VHF D/L +	DABS + ATARS
TERMINAL	118 NON ARTS III TERMINAL SITES	ATCRBS	ATCRBS	ATCRBS
EN ROUTE	120 EN ROUTE SITES	ATCRBS + VHF D/L	ATCRBS + VHF D/L	DABS ONLY (NO ATARS)

*AT 31 HIGH DENSITY TERMINAL SITES, THE EQUIPMENT HAS A 700 AIRCRAFT CAPABILITY (400 AIRCRAFT AT NON HIGH DENSITY SITES).

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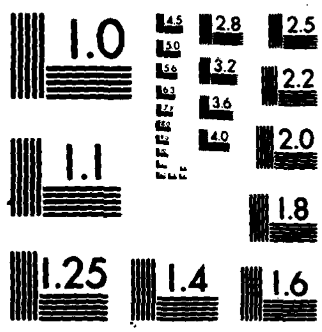

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

TABLE 9-8

EQUIPMENT COMPLEMENT AT GROUND SITES FOR SCENARIO II
UNDER A SAB OR DABS ALTERNATIVE

TYPE OF FACILITY		SAB ALTERNATIVE OPTION I	SAB ALTERNATIVE OPTION II	DABS ALTERNATIVE
TERMINAL	31 HIGH DENSITY ARTS III TERMINAL SITES*	SAB + VHF D/L + ATARS*	SAB + VHF D/L + ATARS*	DABS + ATARS*
TERMINAL	42 OTHER ARTS III TERMINAL SITES	ATCRBS + MONO-PULSE + VHF D/L + ATARS	SAB + VHF D/L + ATARS	DABS + ATARS
TERMINAL	118 NON ARTS III TERMINAL SITES	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE
EN ROUTE	50 EN ROUTE SITES (REQUIRES ATARS TO PROVIDE SINGLE SITE ATARS COVERAGE	ATCRBS + MONO-PULSE + VHF D/L ATARS	SAB + VHF D/L + ATARS	DABS + ATARS
EN ROUTE	70 EN ROUTE SITES (SINGLE SITE ATARS COVERAGE AVAILABLE FROM TERMINAL SITES)	ATCRBS + VHF D/L	ATCRBS + VHF D/L	DABS ONLY (NO ATARS)

*AT 31 HIGH DENSITY TERMINAL SITES, THE EQUIPMENT HAS A 700 AIRCRAFT CAPABILITY (400 AIRCRAFT AT NON HIGH DENSITY SITES).

9.2.3 Ground Equipment -- Total Costs

Table 9-9 presents the total differential ground costs.

9.3 Comparisons of Total Acquisition Costs (Less Installation Costs and Spares for Avionics)

The total acquisition costs under the two scenarios and assumptions and ground rules described above and derived in detail in Appendix A, are shown in Table 9-10. It can be seen that the cost ground equipment of the SAB (4096) based alternative with SAB at just the 31 high density sites might cost around $45M less than the DABS based alternative for Scenario I case while the costs to all civilian user groups would be in favor of the DABS based alternative by about $400M. Further, if one considered only the costs to the air carriers, the high performance GA and 60% of the medium performance GA, the avionic cost differential in favor of the DABS based alternative would more than offset the increased costs of DABS to the government. Further, the cost differential between the DABS and SAB alternatives decreases to only $4M if one assumes an upgrading of the SAB based sites to more nearly approximate the capabilities of the DABS sites (Scenario II, Option 2). The comparative costs favoring the SAB based alternative in the case of the ground equipment and favoring the DABS based alternative in case of the costs to users is shown in Figure 9-1.

TABLE 9-9

TOTAL DIFFERENTIAL* GROUND COSTS
(IN 1976 DOLLARS)

SYSTEM	SCENARIO I	SCENARIO II
DABS + ATARS	$206.4M	$304.0M
SAB (4096) + VHF D/L + ATARS		
- SAB AT HIGH DENSITY TERMINALS ONLY	$160.9M	$277.0M
- SAB AT ALL ATARS SITES	$165.5M	$300.1M

*THE DIFFERENTIAL IS OVER AN ATCRBS SCENARIO ASSUMED IF SAB AND DABS ARE ABSENT.

TABLE 9-10

TOTAL ACQUISITION COSTS

DABS/ATARS VS SAB + VHF D/L + ATARS
($ X 10^6) (1976 $)

	CIVILIAN AVIONIC COSTS					GROUND COSTS		GRAND TOTAL	
	AIR CARRIER	HIGH GA	MED GA	LOW GA	TOTAL	SCENARIO 1	SCENARIO 2	SCENARIO 1	SCENARIO 2
DABS (LSI) + ATARS	29	98	30	154	311	206	304	517	615
DABS (DISCRETE) + ATARS	39	133	65	309	546	206	304	752	850
SAB (4096) + VHF D/L + ATARS (SAB -- HIGH DENSITY TERMINALS)	44	149	104	641	938	161	277	1099	1215
SAB (4096) + VHF D/L + ATARS (SAB -- ALL ATARS SITES)	44	149	104	641	938	166	300	1104	1238

*COSTS OVER AND ABOVE COSTS THAT WOULD HAVE BEEN INCURRED IF ONLY ATCRBS TRANSPONDERS AND VHF VOICE COMMUNICATIONS WERE INSTALLED.

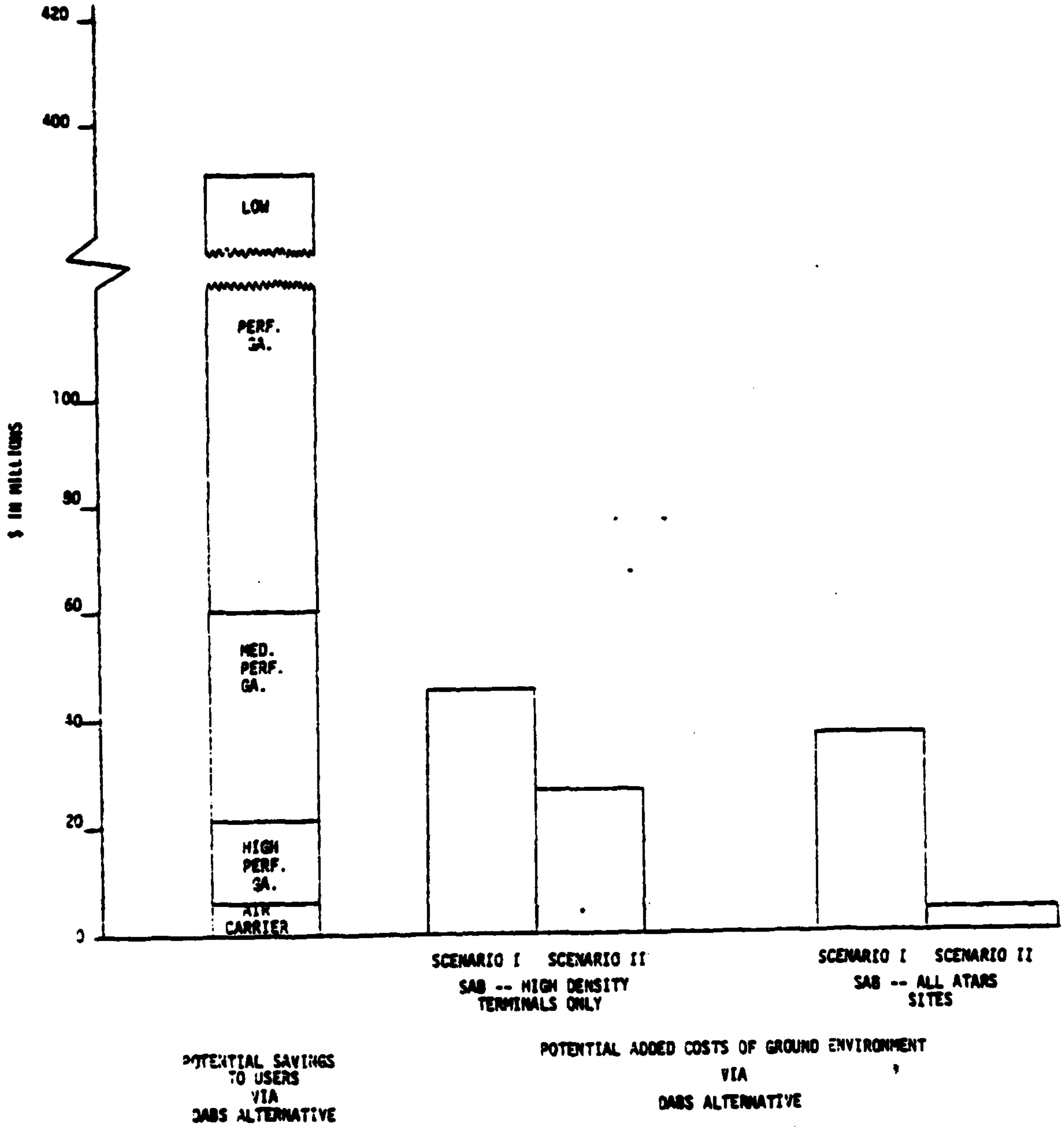

FIGURE 9-1

COMPARISON OF AVIONIC SAVINGS VS GROUND COSTS FOR DABS ALTERNATIVE

It must be remembered that these cost comparisons were based on scenarios that were deliberately selected to show the lowest possible costs for the SAB (4096 + VHF D/L + ATARS alternative. Based on just those cost projections, DABS/ATARS is the preferred alternative. The overall cost differential in favor of the DABS based alternative would become significantly larger, probably if allowances were made for the following:

- Performance diference between the two alternatives
- Costs to the military
- Installation costs for civilian and military aircraft
- The fact that more civilian aircraft would have to purchase an additional VHF transceiver than assumed herein in order to get the VHF data link capability. (The true costs to the civilian aviation community is probably grossly understated by the assumptions that air carrier aircraft, high performance GA aircraft, medium performance GA aircraft, and 50% of the low performance GA aircraft with dual transceivers would be able to or elect to use on-board transceivers to obtain the VHF data link capability.)

For additional considerations, see the discussion which follows in Section 10.

10. OTHER CONSIDERATIONS

The previous sections concentrated essentially on the economic aspects of the two major alternate system configurations -- (1) DABS + ATARS + BCAS and (2) SAB + VHF D/L + ATARS + BCAS -- and concluded that significant economic benefit existed in the selection of the DABS alternative. Beyond the economic aspects, there are several additional considerations which are very important and weigh heavily on the final selection. Some of these will be addressed briefly in this section.

10.1 Integrated System

Many of the projected benefits predicted for the future ATC system require achieving both an improved surveillance capability as well as a digital data link system. In DABS, both of these features are combined into a single integrated unit which, once implemented, will provide the essential backbone required to achieve the improved safety and automation benefits.

The alternate approach -- SAB + VHF -- does not have this important characteristic. Incremental benefits would be achieved in suveillance improvements with SAB and in the area of data link with VHF, but the synergetic effect of having both capabilities is substantially greater than each of these separate incremental benefits imply.

Consider collision avoidance as a prime example. Both improved surveillance and a digital data link are required to provide the best quality collision avoidance service. Improved surveillance is needed to accurately track and locate the aircraft (in all types of densities), and a digital data link for coordination of maneuvers and transmission of commands (ground-to-air and air-to-air). Neither one of these separate improvements alone will provide the needed capabilities in itself -- both are simultaneously required.

The integrated approach inherent in DABS combines both capabilities in one low-cost avionics unit which allows one to achieve these benefits simultaneously in one step. In contrast, an approach which requires a separate system to improve surveillance and an additional unit to achieve data link would be significantly more costly to implement and would be wasteful of the RF spectrum; likely require significant additional time before substantial equipage with both capabilities would be achieved; and be much more difficult to manage.

10.2 User Reactions -- The Need for SAB Regulation

Implementation of new systems in the aviation area has historically proven to be a long and laborous task essentially paced by the user community reaction to the new device or capability. Clearly, minimizing the burden of the user community implies low-cost integrated avionics whenever possible.

Consider, for example, the prospects for wide scale general aviation equipage on a voluntary basis with a stand-alone SAB transponder. In the eyes of the general aviation pilot, the preceived beneficiary of the device is the ground based ATC system. The user who takes no other action other than replacing his present ATCRBS transponder with a SAB transponder will, in reality, obtain no immediate observable benefit. In the absence of mandatory retrofit requirements, the user's motivation to make this change will be minimal. While this point is quite subtle, it has in fact been a key factor cited frequently by these users who have not yet equipped with ATCRBS or who were slow to equip. Indeed, in interviews with these users, the frequent criticism of "I get nothing in return" has been cited as a primary lack of motivation. At the Federal level, the only effective method of dealing with this problem is through regulations. Thus, foresight would indicate that mandatory regulation of SAB would be necessary.

In contrast, the FAA strategy for DABS implementation is to offer new user services -- such as collision avoidance and data link -- in a time frame similar to that of implementation of the DABS ground station. It is anticipated that these new services -- which make use of both the surveillance and data link capabilities of DABS -- will provide an incentive for voluntary equipage with DABS transponders in the absence of regulatory action.

Extensive discussions have been held over the past several years with representatives of the user groups. These have been both formal and informal in nature. Substantial support for proceeding with DABS has been obtained from a variety of interests recognizing the fact that DABS represents an integrated approach which can be achieved in an evolutionary manner.

10.3 Performance

In the cases considered, the deployment of the DABS alternative results in a better surveillance capability than the SAB based alternative. This is because DABS is deployed at all en route sites and all the ARTS-III terminal sites in order to obtain the data link capability and support advanced automation to increase controller productivity while in the SAB case only the VHF D/L is deployed at those sites but with no change in the secondary surveillance capability. As a result, the DABS deployment automatically provides for an improved surveillance for those sites.

Additionally, the SAB (4096) system would require manual procedures in order for aircraft not equipped with the auto-tune capability to obtain entry into the system. The use of SAB (4096) also allows for for the undesirable possibility that two or more aircraft flying in the same general airspace may be assigned the same code.

Thus, the DABS alternative would provide a better surveillance capability and would eliminate some of the procedures that would have to be used with a SAB (4096) code system.

10.4 Impact on Military

Throughout this analysis, the impact of each alternate on the military has not been considered (except in the ACAS/BCAS comparison). A little reflection will indicate that consideration of the DOD impact would significantly strengthen the case for the DABS alternative. As shown in the ACAS/BCAS analysis and in previous analysis of the DOD AIMS program (a DOD program to implement altitude reporting transponders), the "black box" installation and logistics support costs -- particularly in tactical type of aircraft far exceed the acquisition costs. Factors as high as 5:1 are not unrealistic.

Considering DOD's active fleet of approximately 20,000 aircraft, the advantage to the DOD by supporting one integrated unit -- the DABS -- when compared to installing two separate "black boxes" -- one for SAB and another for VHF data link -- would be quite substantial. The DABS or the SAB transponder could be built as a "form and fit" replacement to the existing APX-72 or equivalent military transponder, but the VHF data link would clearly require additional installation provisions. An average installation increment of $10,000 for VHF data link for DOD aircraft spread over 20,000 aircraft for a total of $200M in favor of the DABS alternative may not be at all unrealistic.

11. CONCLUSIONS

From the preceding discussion, it can be stated that:

- Improvements in surveillance and communications are needed to support advanced automation programs aimed at improving safety, increasing controller productivity, and providing pilots with improved ATC services.

- BCAS is clearly preferred to ACAS for collision avoidance protection outside of ATARS coverage.

- The overall costs to users plus the government are strongly in favor of the DABS + ATARS + BCAS alternative.

- Savings to users far outweigh any additional cost to the government even if assumptions are deliberately picked to heavily favor the SAB (4096) + VHF D/L + ATARS + BCAS alterntive.

- The DABS/ATARS alternative would provide better performance than the SAB (4096) based alternative. Performance more closely approximating the performance of DABS could be realized by using a more complex SAB designed to have a unique addressing capability but at an even greater cost disadvantage to the users.

- The need for initial regulation can be avoided with the DABS + ATARS + BCAS alternative. Other alternatives do not have this important benefit.

- Implementation management and installation and cost management weighs strongly in favor of an integrated system -- DABS.

In summary, based upon an assessment of other proposed alternatives, DABS is clearly the preferred approach to achieving the improved surveillance and communication improvements to support planned improvements to the ATC system.

APPENDIX A

COMPARISON OF AVIONIC AND GROUND SYSTEMS COSTS OF DABS/ATARS VS. SAB + VHF D/L + ATARS

1. INTRODUCTION

The analysis presented here develops and compares the differential avionic and ground site costs of a DABS/ATARS scenario versus a SAB scenario with VHF data link and ATARS. Since the purpose of the analysis is to evaluate the two alternatives on a cost basis, the scope of this effort is limited to the estimation of incremental costs and hence, avionic and ground system elements common to both scenarios are not addressed. The general guidelines listed below have been followed in each part of the analysis:

1. Annual O&M costs are not considered. Recurring O&M costs are assumed to be a given percent of F&E costs and therefore do not change the selection of alternatives on a cost basis.

2. All costs are in constant 1976 dollars because the primary references present unit costs in terms of 1976 dollars. Updating to 1978 dollars only involves multiplication by a constant factor with no impact on the selection process.

3. The analysis period is assumed to be 1984-1993.

4. To simplify the impact of complex hypothesized transition scenarios, annual costs are not discounted. A straight addi-

tion of undiscounted costs depends only on the beginning and end phases and not on the details of the mechanics of transitions.

5. When in doubt, the SAB scenario costs are kept as low as possible in order to be on the conservative side with respect to the relative merits of the DABS alternative.

The next two sections develop the avionic and ground costs of interest and also discuss additional assumptions made in the process. Section 4 presents the total differential cost comparison of the two systems.

2. AVIONIC COSTS

The development of the avionic costs is based on unit cost estimates from reports of ARINC Research Corporation. The costs of interest are incremental costs of purchasing new equipment or modifying old equipment needed to realize improved service. The unit costs used in this analysis do not include installation costs. Installation costs are not included because a complete and consistent set of installation costs is not available. In any case, the installation costs between DABS and SAB avionics are expected to be either similar for comparable elements or else higher for the SAB scenario due to the fact that more avionic components have to be installed. Hence, the exclusion of installation costs is consistent with the philosophy of when in doubt keep the SAB scenario costs as low as possible.

Military fleet and associated avionic costs are not a part of this study due to unvalidated data on SAB/VHF data link costs for the military. Furthermore, on a unit cost basis, the military costs under a SAB scenario are expected to be substantially higher than those under a DABS scenario. This judgment is based on the fact that DABS scenario requires the replacement of ATCRBS transponder with DABS transponder and a display while the SAB scenario requires modifications to the ATCRBS transponder plus a display plus a data modem with other changes to the military UHF/VHF transceivers also likely. Subsequently, the omission of military fleet from the analysis results in a cost comparison which is heavily weighted in favor of the SAB system.

It is further assumed that those aircraft forecast to leave the fleet during the analysis period do not equip with any modifications or new avionics and that all new aircraft that equip do so with new avionic capability (SAB or DABS as appropriate). This study does not consider any residual value of existing equipment because they would be the same under both, DABS and SAB, scenarios and would not contribute to the differential costs. Other assumptions dealing with the actual equipage, fleet sizes and unit costs are discussed in the following subsections as appropriate.

2.1 User Groups, Fleet Sizes and Equipment Complements

The civil aviation users have been classified into four categories and are equipped with one of two classes of avionics (high cost

avionics designed to meet ARINC specifications and a less sophisticated low cost avionics):

1. Air Carriers--representing the most sophisticated class of civilian users are equipped with redundant high cost avionics.

2. High Performance General Aviation--assumed to include all turbine powered GA and 10% of multiple engine GA aircraft. This class of users equips with high cost avionics comparable to the air carriers but without the redundancy of the equipment.

3. Medium Performance General Aviation--assumed to comprise the remaining (90%) of the multiple engine GA aircraft. The equipage in this category consists of single low cost avionics.

4. Low Performance General Aviation--consists of all single engine GA fleet. Not all the users in this category would equip their aircraft with DABS or SAB avionics. Those who equip do so with a single low cost avionics.

The fleet forecasts for these four user classes over the ten year analysis period (1984-1993) are shown in Table A-1. The most recent official FAA forecasts (Reference A1) formed the basis for these projections. The FAA forecasts covered the period up to 1989. For the 1990-1994 time frame, projections were made on a constant growth rate assumption. The growth rate used was the increase from 1988 to

TABLE A-1

FLEET FORECASTS

YEAR	AIR CARRIER			HIGH GA (x 1000)			MEDIUM GA (x 1000)			LOW GA (x 1000)		
	TOTAL (JAN 1)	RETIRED	NEW	TOTAL	RETIRED	NEW	TOTAL	RETIRED	NEW	TOTAL	RETIRED	NEW
1984	2,913	35	97	12.8	.3	1.1	30.7	.6	2.1	201.1	4.0	10.3
1985	2,975	36	90	13.6	.3	1.5	32.2	.6	1.9	207.4	4.1	9.4
1986	3,029	36	86	14.8	.3	1.3	33.5	.7	2.0	212.7	4.3	8.7
1987	3,079	37	88	15.8	.3	1.3	34.8	.7	1.8	217.1	4.3	8.3
1988	3,130	38	91	16.8	.3	0.7	35.9	.7	1.5	221.1	4.4	9.1
1989	3,183	38	92	17.2	.3	0.7	36.7	.7	1.5	225.8	4.5	9.2
1990	3,237	39	94	17.6	.4	0.8	37.5	.8	1.6	230.5	4.6	9.4
1991	3,292	40	96	18.0	.4	0.8	38.3	.8	1.7	235.3	4.7	9.6
1992	3,348	40	97	18.4	.4	0.8	39.2	.8	1.7	240.2	4.8	9.8
1993	3,405	41	99	18.8	.4	0.8	40.1	.8	1.7	245.2	4.9	10.0
1994	3,463			19.2			41.0			250.3		
TOTAL:		380	930		3.4	9.8		7.2	17.5		44.6	93.8

1989--the last two years of the FAA forecasts. Based on inputs from the Office of Aviation Forecasts of the FAA, the retirement rates of 1.2% for air carriers and 2.0% for general aviation were assumed. The forecast of total fleet size and the retirement rate determined the number of new aircraft for each category:

New aircraft in year N = Fleet size in year (N + 1) - Fleet size in year N + Number of aircraft retired in year N.

To be able to estimate the differential costs of DABS vs. SAB scenario, certain assumptions have to be made about the level of avionic equipage for each class of users. Table A-2 presents a summary of the relevant avionic equipage. The assumptions of air carrier and high and medium performance GA equipage are self explanatory. The class of low performance GA requires some explanation. In an ATCRBS scenario (absence of DABS or SAB), it is expected that the level of equipage of this class would increase due to the expected trends in the GA community as well as a higher degree of expected interactions with the ATC system. By 1993, it is assumed that 70% of the fleet would have an ATCRBS transponder and either one (40%) or two (30%) VHF transceivers. The other 30% would not have a transponder and only some of them would have a VHF transceiver. Similar guidelines are assumed for the old aircraft under a DABS scenario. The new aircraft are expected to have a higher level of

TABLE A-2

BASIC EQUIPMENT COMPLEMENT OF USER CLASSES UNDER DIFFERENT SCENARIOS
OVER THE STUDY PERIOD (1984-1993)

USER CLASS	ATCRBS SCENARIO (ABSENCE OF DABS OR SAB)	DABS SCENARIO	SAB SCENARIO
AIR CARRIERS	100% OF THE FLEET-- 2 ATCRBS 2 <u>OR</u> 3 VHF TRANSCEIVERS	100% OF THE FLEET-- 2 DABS + ATARS 2 <u>OR</u> 3 VHF TRANSCEIVERS	100% OF THE FLEET-- 2 SAB + ATARS 2 D/L MODEMS 2 <u>OR</u> 3 VHF TRANSCEIVERS
HIGH AND MEDIUM PERFORMANCE GEN. AV.	100% OF THE FLEET-- 1 ATCRBS 2 VHF TRANSCEIVERS	100% OF THE FLEET-- 1 DABS + ATARS 2 VHF TRANSCEIVERS	100% OF THE FLEET-- 1 SAB + ATARS 1 D/L MODEM 2 VHF TRANSCEIVERS
LOW PERFORMANCE GEN. AV.	15% OF THE FLEET IN 1984 INCREASING TO 30% IN 1993-- 1 ATCRBS 2 VHF TRANSCEIVERS 25% OF THE FLEET IN 1984 INCREASING TO 40% IN 1993-- 1 ATCRBS 1 VHF TRANSCEIVER 60% OF THE FLEET IN 1984 DECREASING TO 30% IN 1993-- NO ATCRBS VARIABLE EQUIPAGE FOR TRANSCEIVERS	<u>BY THE YEAR 1993</u> <u>NEW AIRCRAFT</u> 40% OF THE FLEET-- 1 DABS + ATARS 2 VHF TRANSCEIVERS 40% OF THE FLEET-- 1 DABS + ATARS 1 VHF TRANSCEIVER 20% OF THE FLEET-- NO (DABS + ATARS) OLD AIRCRAFT THE FLEET PERCENT FOR THE EQUIPAGE SHOWN ABOVE ARE 30%, 40%, 30%, RESPECTIVELY	<u>BY THE YEAR 1993</u> <u>NEW AIRCRAFT</u> 80% OF THE FLEET-- 1 SAB + ATARS 2 VHF TRANSCEIVERS 20% OF THE FLEET-- NO (SAB + ATARS) OLD AIRCRAFT THE FLEET PERCENT FOR THE EQUIPAGE SHOWN ABOVE ARE 70% AND 30% RESPECTIVELY

equipage and hence 80% are assumed to be DABS/ATARS equipped (40% with single and 40% with dual transceivers). To keep a comparable level of avionic equipage under the SAB scenario, 70% of the old and 80% of the new aircraft are equipped with SABS + ATARS. In this case, however, the presence of VHF D/L with the SAB + ATARS requires 2 VHF transceivers (one for data link and the other for voice communications) for all aircraft that are equipped with SAB. As mentioned earlier in Section 1, the exact mechanics of the transition phase under the DABS or SAB scenario is not relevant to this analysis.

2.2 Unit Costs

The price of the avionic components, as shown in Table A-3, are based on References A2 through A4 -- reports by The ARINC Research Corporation for the FAA. In developing the cost estimates, ARINC considered only two classes of avionics -- one for air carriers and high performance GA aircraft and the other for medium and low performance GA aircraft. Based on its observations of the general practice in the selling of avionics, ARINC assumed that the cost of the equipment purchased for high performance aircraft would be 30% higher than the price paid by air carriers when purchasing in large quantities. The avionics list price for the medium and low performance GA aircraft was estimated by ARINC to be the factory selling price plus a 100% mark-up by the distributor.

TABLE A-3

AVIONICS COST PER UNIT

(1976 $)

	AIR CARRIER	HIGH PERFORMANCE GA	MEDIUM AND LOW PERFORMANCE GA
DABS/ATARS			
Transponder (LSI)	5212	6776	1352*
Transponder (Discrete)	6625	8612	1082
Control Box	516	516	Included
ATARS Display**	2198	2857	1110
Antenna	63	75	13
SAB (4096)			
Transponder	4176	5429	784
Control	516	516	Included
Antenna	63	75	13
SAB Adapter	1201	1561	N/A
ATCRBS			
Transponder	3975	5169	612
Control	516	516	Included
Antenna	63	75	13
VHF D/L + ATARS			
Transceiver	2500	3250	1254
Control Box	516	516	Included
Data Modem**	2845	3699	1240
ATARS Display**	2198	2857	1114
Auto-tune	299	389	N/A***
Antenna	180	240	16

*Includes ATARS display as part of integral transponder/display unit.

**Based on discrete technology. LSI technology version should have lower costs.

***Not available in low cost avionics.

The SAB adapter costs are from Reference A4 and the cost of DABS transponder (discrete) are based on an earlier ARINC report (Reference A3). The cost of DABS transponder (discrete) as shown in Table A-3 is updated from the one in Reference A3 to be compatible with the latest ARINC estimates of the DABS transponder (LSI) cost (Reference A2) in 1976 dollars as follows:

Cost of DABS (Discrete) transponder in 1976 dollars:

$$= \text{Cost of DABS (Discrete) transponder in Reference A3} \times \frac{\text{Cost of DABS (LSI) transponder in Reference A2}}{\text{Cost of DABS (LSI) transponder in Reference A3}}$$

SAB and VHF data link equipment costs using LSI technology were not developed by ARINC. Hence, the DABS costs using discrete component technology should be used for purposes of comparative evaluation even though DABS (LSI) costs may be realized if the industry elects to apply that technology. Costs of encoding altimeters and ATC displays are the same in both alternatives and hence are not considered in this analysis.

These unit costs can then be used to evaluate the differential between the DABS and the SAB scenario as described in Section 2.1. Tables A-4 and A-5 show the incremental cost per aircraft for each user class under a DABS or a SAB scenario for new and existing aircraft respectively. The incremental cost is over an ATCRBS scenario in the absence of DABS or SAB. In developing these tables,

TABLE A-4

INCREMENTAL EQUIPMENT COSTS OF ACHIEVING IMPROVED PERFORMANCE
(1976 DOLLARS)

NEW AIRCRAFT

USER CLASS	DABS SCENARIO		SAB SCENARIO	
	ADDITIONAL EQUIPMENT	ADDED COSTS	ADDITIONAL EQUIPMENT	ADDED COSTS
AIR CARRIER	2(Δ DABS + ATARS)	6,870 (LSI) 9,696 (DISCRETE)	2(Δ SAB + ATARS + DATA MODEM + AUTO TUNE)	11,036
HIGH PERF. GEN. AV.	1(Δ DABS + ATARS)	4,464 (LSI) 6,300 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM + AUTO TUNE)	7,205
MEDIUM PERF. GEN. AV.	1(Δ DABS + ATARS)	740 (LSI) 1,580 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM)	2,526
LOW PERF. GEN AV.	1(Δ DABS + ATARS)	740 (LSI) 1,580 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM)	2,526
	1(DABS + ATARS)	1,365 (LSI) 2,205 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM + VHF TRANS. W ANT.)	3,796
	1(Δ DABS + ATARS + VHF TRANS. W ANT.)	2,010 (LSI) 2,850 (DISCRETE)	1(SAB + ATARS + DATA MODEM + VHF TRANS. W ANT.)	4,421

Δ = INCREMENTAL COST OVER ATCRBS TRANSPONDER

TABLE A-5

INCREMENTAL EQUIPMENT COSTS OF ACHIEVING IMPROVED PERFORMANCE
(1976 DOLLARS)

EXISTING AIRCRAFT

USER CLASS	DABS SCENARIO		SAB SCENARIO	
	ADDITIONAL EQUIPMENT	ADDED COSTS	ADDITIONAL EQUIPMENT	ADDED COSTS
AIR CARRIER	2(Δ DABS + ATARS)	6,870 (LSI) 9,696 (DISCRETE)	2(Δ SAB + ATARS + DATA MODEM + AUTO TUNE + CONTROL BOX)	12,118
	2(Δ DABS + ATARS) + VALUE OF EXISTING ATCRBS TRANSPONDER*	10,845 (LSI) 13,671 (DISCRETE)	2(SAB ADAPTER + ATARS + DATA MODEM + AUTO TUNE + CONTROL BOX)	14,118
HIGH PERFORMANCE GENERAL AVIATION	1(Δ DABS + ATARS)	4,464 (LSI) 6,300 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM + AUTO TUNE + CONTROL BOX)	7,721
	1(Δ DABS + ATARS) + VALUE OF EXISTING ATCRBS TRANSPONDER*	7,049 (LSI) 8,885 (DISCRETE)	1(SAB ADAPTER + ATARS + DATA MODEM + AUTO TUNE + CONTROL BOX)	9,022
MEDIUM PERFORMANCE GENERAL AVIATION	1(Δ DABS + ATARS)	740 (LSI) 1,580 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM)	2,526
LOW PERFORMANCE GENERAL AVIATION	1(Δ DABS + ATARS)	740 (LSI) 1,580 (DISCRETE)	1(Δ SAB + ATARS + DATA MODEM)	2,526
			1(Δ SAB + ATARS + DATA MODEM + VHF TRANS. W ANT.)	3,796

Δ = INCREMENTAL COST OVER ATCRBS TRANSPONDER

* ASSUMED TO BE 50% OF THE ORIGINAL VALUE BASED ON HALF THE EXPECTED LIFE ON AN AVERAGE.

it is assumed that existing aircraft of medium and low performance GA class do not pay for any 4096 control box under a SAB scenario. This is consistent with the guideline "when in doubt keep the cost of SAB as low as possible." A comparison of DABS and SAB costs (Tables A-4 and A-5) show that the cost under a SAB scenario is higher in every case.

2.3 Total Differential Avionic Costs

Using the unit costs developed in the previous section and the fleet sizes and equipment complements as discussed in Section 2.1, the total differential avionic costs can be developed for each of the two scenarios (DABS or SAB). These differential costs, as shown in Table A-6, are additional avionic costs over an ATCRBS scenario as envisioned in the absence of DABS or SAB. These costs are based on two additional assumptions for existing aircraft:

1. Under a SAB option, 50% of air carrier and high performance GA as well as 100% of medium and low performance GA replace the ATCRBS avionics. The remaining 50% of air carrier and high performance GA modify the ATCRBS avionics for use in the SAB environment. This assumption is based on the rationale that half the air carrier and high performance GA will have an ATCRBS transponder with sufficient useful life remaining to warrant a modification instead of replacement. To keep the DABS scenario compatible with this assumption, it is assumed that the average value of the existing ATCRBS transponders (being replaced by DABS transponders) is half the original

TABLE A-6

TOTAL DIFFERENTIAL* AVIONICS COSTS
($ X 10^6)

	A/C			HIGH GA			MEDIUM GA			LOW GA		
	NEW	RETRO	TOTAL	NEW	RETRO	TOTAL	NEW	RETRO	TOTAL	NEW	RETRO	TOTAL
DABS + ATARS (LSI) GRAND TOTAL: 311	6.389	22.434	28.823	43.747	54.111	97.858	12.950	17.390	30.340	73.305	81.067	154.372
DABS + ATARS (DISCRETE) GRAND TOTAL: 546	9.017	29.592	38.609	61.740	71.370	133.110	27.650	37.130	64.780	136.338	173.089	309.427
SAB + D/L + ATARS GRAND TOTAL: 938	10.310	33.227	43.537	70.609	78.692	149.301	44.205	59.361	103.566	254.977	386.039	641.016

*DIFFERENTIAL IS TAKEN OVER AN ATCRBS SCENARIO ASSUMED TO EXIST IN THE ABSENCE OF DABS OR SAB.

value for those 50% of air carrier and high performance GA fleet that have ATCRBS transponders with some useful life remaining.

2. All VHF transceivers can provide data link by adding a modem and control for air carriers, high and medium performance GA, and 50% of those low performance GA that are equipped with dual transceivers. It is assumed that the remaining 50% of low performance GA that are equipped with dual transceivers do not have transceivers of a quality that can be upgraded by adding modem and control and hence, these transceivers need to be replaced to provide the upgraded capability.

The total differential avionics costs over the analysis period are estimated at $311M for DABS (LSI), $546M for DABS (discrete), and $938M for SAB (4096) scenarios respectively. The breakdown of these costs by user classes and new/existing aircraft are also shown in Table A-6.

3. GROUND COSTS

The estimates of ground equipment costs are based on unit cost data provided by the FAA. The costs developed here are in 1976 dollars and represent incremental cost of additional equipment required under the scenarios of interest. This is compatible with the assumptions of the avionic costs. The costs for ground sites include equipment, installation and spares but not operating and maintenance (O&M) costs. As discussed earlier, O&M costs estimated as a percent of F&E costs would not change the selection of alternatives on a cost basis.

The SAB alternative was developed to take full advantage of the flexibility provided by the separation of improved surveillance via SAB and improved communications via a separate VHF data link. As a result not all sites that have DABS in the DABS scenario have the selective addressing capability in the SAB scenario. Consequently, the total capability of the system under a SAB scenario is not as sophisticated as that of a DABS scenario. This assumption will be further discussed in Section 3.1 when the scenarios are developed.

In addition, it was assumed that the antennas at the terminal sites would have been upgraded before the start of the analysis period 1984-1993. This provides for a capability of using these antennas without any additional cost under both (DABS or SAB) scenarios. For those en route sites receiving ATARS capability, it was assumed that back-to-back antennas will be installed in order to improve the update rate required to support ATARS.

The scenarios for the ground sites are developed in Section 3.1 and their costs in the following scenarios.

3.1 Implementation Scenarios and Equipment Complements

Two sets of scenarios were developed solely for the purpose of comparing alternatives. FAA is in the process of defining official FAA implementation plans. HENCE, THE SCENARIOS DISCUSSED IN THIS

ANALYSIS SHOULD NOT BE CONSTRUED AS AN OFFICIAL FAA POLICY OR PLAN. The basis of these two scenarios are as follows:

Scenario 1: Minimum Deployment

- Provide a data link capability at all en route surveillance sites and at all terminal sites with ARTS-III to achieve increased controller productivity via advanced automation which automatically generates ATC messages and transmits the messages to and from aircraft via a data link.

- Provide selective or discrete addressing at only 21 high density areas (31 surveillance sites) to insure surveillance that is free of synchronous garble problems. Assume that ATCRBS with monopulse detection would be acceptable at other sites scheduled to receive ATARS. Assume that ATCRBS would continue to be used at the remaining sites.

- Install ATARS at just the terminal sites (73) serving ARTS-III facilities to provide increased aircraft separation assurance both inside TCA/TRSA airspace and outside the TCA/TRSA airspace but within coverage of the surveillance site. Assume that additional protection to large passenger aircraft would be realized in low density airspace via BCAS.

Scenario 2: Maximize Single Site Coverage for ATARS

Use the same ground rules as for Scenario 1 except as follows:

- Install ATARS at all terminal surveillance sites to provide maximum aircraft separation services in the terminal areas where most midair and near-midair collisions occur.

- Install ATARS at as many en route sites as necessary (50) to maximize single site ATARS coverage; conversely, do not install ATARS at en route surveillance sites where single site coverage is obtainable from the terminal sites.

The equipment complement of ground sites for these two scenarios under both (DABS or SAB) alternatives are shown in Table A-7. As mentioned earlier, the SAB alternative does not provide the same system capabilities as a DABS alternative does. Specifically, in Scenario 1, 42 low density ARTS-III sites and 120 en route sites do not have a SAB (4096) capability but do have DABS installations. Such sites have the discrete addressing capability under DABS environment but do not have a selective addressing capability under the SAB environment. Under Scenario 2, the same difference exists at 160 terminal sites and 120 en route sites. It is possible to partially bridge this gap in capabilities by providing SAB instead of IATCRBS with monopulse at all ATARS sites. The additional cost associated with this change is estimated and presented in the cost sections. There is, however, a continuing difference in SAB vs. DABS alternatives in the area of unique addressing of aircraft. To bring the SAB alternative to the DABS level of service would require additional costs of SAB (unique) vs. SAB (4096) at ground

TABLE A-7

EQUIPMENT COMPLEMENT AT GROUND SITES FOR TWO HYPOTHESIZED SCENARIOS UNDER A SAB OR DABS ALTERNATIVE

	TYPE OF FACILITY	SCENARIO 1		SCENARIO 2	
		SAB ALTERNATIVE	DABS ALTERNATIVE	SAB ALTERNATIVE	DABS ALTERNATIVE
TERMINAL	31 HIGH DENSITY ARTS III TERMINAL SITES*	SAB + VHF D/L + ATARS*	DABS + ATARS*	SAB + VHF D/L + ATARS*	DABS + ATARS*
	42 OTHER ARTS III TERMINAL SITES	IATCRBS + MONO-PULSE + VHF D/L + ATARS	DABS + ATARS	IATCRBS + MONO-PULSE + VHF D/L + ATARS	DABS + ATARS
	118 NON ARTS III TERMINAL SITES	IATCRBS	IATCRBS	SAME AS ABOVE	SAME AS ABOVE
EN ROUTE	50 EN ROUTE SITES (REQUIRES ATARS TO PROVIDE SINGLE SITE ATARS COVERAGE)	IATCRBS + VHF D/L	DABS ONLY (NO ATARS)	IATCRBS + MONO-PULSE + VHF D/L + ATARS + BACK-TO-BACK ANTENNA	DABS + ATARS
	70 EN ROUTE SITES (SINGLE SITE ATARS COVERAGE AVAILABLE FROM TERMINAL SITES)	SAME AS ABOVE	SAME AS ABOVE	IATCRBS + VHF D/L	DABS ONLY (NO ATARS)

*AT 31 HIGH DENSITY TERMINAL SITES THE EQUIPMENT HAS A 700 AIRCRAFT CAPABILITY (400 AIRCRAFT AT NON HIGH DENSITY SITES).

sites as well as the related avionic cost increases. The SAB (unique) alternative has not been addressed here but would clearly require higher costs for the FAA (ground sites) and the users (avionics).

3.2 Unit Costs

The unit costs used in estimating the differential costs of the alternatives are shown in Table A-8. In addition to these costs, FAA also estimated $110K per site as the incremental cost of providing SAB (4096) over IATCRBS with monopulse, and $150K for providing back-to-back antennas at each en route site where required. For terminal sites, two levels of capabilities were evaluated -- 400 aircraft option for low density terminals and 700 aircraft option for high density terminals.

The incremental package costs as shown in Table A-9 reflect these unit costs and form the basis of estimating incremental ground site costs for the SAB or DABS alternatives under the two scenarios.

3.3 Total Differential Ground Costs

The equipment unit and package costs developed in the previous section is used to estimate the total differential ground costs of the two scenarios for a SAB or a DABS environment. These costs represent the additional costs incurred in each scenario over an ATCRBS scenario which would exist in the absence of SAB or DABS.

TABLE A-8

INCREMENTAL COSTS* OF NEW CAPABILITIES
AT ATCRBS GROUND SITES

(IN THOUSANDS OF 1976$)

CAPABILITY	TERMINAL SITES 400 A/C	TERMINAL SITES 700 A/C	EN ROUTE SITES
ATCRBS**	199	219	289
ATCRBS + MONOPULSE DETECTION	590	650	680
SAB (4096)	700	760	790
VHF D/L	198	324	198
ATARS (NON DABS)	143	203	293
SAB (4096) + VHF D/L + ATARS	1041	1287	1281
DABS + ATARS	950	1052	1100
DABS W/O ATARS	NOT USED	NOT USED	920***
SOURCE: FAA, AUGUST 1978			

*COSTS INCLUDE INSTALLATION AND INITIAL SPARES

**UPGRADING COSTS BETWEEN NOW AND START OF IMPLEMENTATION OF DABS OR SAB BUT DOES NOT INCLUDE FUNDS FOR ANY IMPROVEMENTS OR REPLACEMENT OF EN ROUTE ANTENNAS

***DABS + ATARS ($1100K) MINUS $100K FOR ATARS PROCESSORS AND $20K ALLOWANCE FOR INITIAL SPARES AND INSTALLATION AND $60K FOR DELETION OF BACK-TO-BACK ANTENNA.

TABLE A-9

INCREMENTAL PACKAGE COSTS OF NEW CAPABILITIES AT ATCRBS GROUND SITES

(IN THOUSANDS OF 1976$)

EQUIPMENT	TERMINAL SITES		EN ROUTE SITES
	400 A/C	700 A/C	
IATCRBS ONLY	199	*	*
IATCRBS + VHF D/L	*	*	487
IATCRBS + MONOPULSE + VHF D/L + ATARS	931	*	*
IATCRBS + MONOPULSE + VHF D/L + ATARS + BACK-TO-BACK ANTENNA	*	*	1081
INCREMENTAL COST OF SAB (4096) OVER IATCRBS + MONOPULSE	110	*	110
SAB (4096) + VHF D/L + ATARS	*	1287	*
DABS ONLY	*	*	920
DABS/ATARS	950	1052	1100

*NOT USED

The costs as shown in Table A-10, indicate that DABS ground costs are higher than SAB ground costs by about $45M for Scenario 1 and $27M for Scenario 2. If SAB (4096) is implemented at all ATARS sites the difference is $41M for Scenario 1 and $4M for Scenario 2.

4. COMPARISON OF TOTAL (AVIONIC + GROUND) COSTS

The total costs of SAB and DABS alternatives, as developed under the ground rules and assumptions of this study, are presented in Table A-11 for Scenarios 1 and 2. These costs are additional costs that would be incurred for each alternative over a system with only ATCRBS equipment and VHF voice communications and no data link capability.

The additional costs of ground sites under DABS + ATARS vs. SAB (4096) + VHF D/L + ATARS are very small when compared to the avionic savings of the two alternatives. The DABS alternative has a net gain of more than $345M over the SAB alternative with SAB (4096) at high density terminals only. If SAB (4096) is implemented at all ATARS sites the DABS alternative's net gain increases to over $350M-$385M depending on Scenario 1 or 2.

In addition to the lower capability of ground sites in a SAB environment, all assumptions in this study have been made to keep the cost of the SAB alternative as low as possible. The conclusion, based

TABLE A-10

TOTAL DIFFERENTIAL* GROUND COSTS
(IN 1976 DOLLARS)

SYSTEM	SCENARIO 1	SCENARIO 2
DABS + ATARS	\$206.4M	\$304.0M
SAB (4096) + VHF D/L + ATARS		
- SAB AT HIGH DENSITY TERMINALS ONLY	\$160.9M	\$277.0M
- SAB AT ALL ATARS SITES	\$165.5M	\$300.1M

*THE DIFFERENTIAL IS OVER AN ATCRBS SCENARIO ASSUMED IF SAB AND DABS ARE ABSENT.

TABLE A-11

TOTAL DELTA* COSTS

DABS/ATARS VS SAB + VHF D/L + ATARS
($ X 10^6) (1976 $)

	CIVILIAN AVIONIC COSTS					GROUND COSTS		GRAND TOTAL	
						SCENARIO		SCENARIO	
	AIR CARRIER	HIGH GA	MED GA	LOW GA	TOTAL	1	2	1	2
DABS (LSI) + ATARS	29	98	30	154	311	206	304	517	615
DABS (DISCRETE) + ATARS	39	133	65	309	546	206	304	752	850
SAB (4096) + VHF D/L + ATARS (SAB -- HIGH DENSITY TERMINALS)	44	149	104	641	938	161	277	1099	1215
SAB (4096) + VHF D/L + ATARS (SAB -- ALL ATARS SITES)	44	149	104	641	938	166	300	1104	1238

*COSTS OVER AND ABOVE COSTS THAT WOULD HAVE BEEN INCURRED IF ONLY ATCRBS TRANSPONDERS AND VHF VOICE COMMUNICATIONS WERE INSTALLED.

on the results of this analysis, is that DABS/ATARS is the preferred alternative on a cost basis.

The conclusion would not change if one were to account for a discounting of the cash flow. Assuming a uniform distribution of avionic and ground site costs over the ten year period and a 5% discount rate (a lower rate then the usual 10% rate is used due to high inflation), the net gain (discounted to 1984) of the DABS alternative over the SAB alternative is between $280-295M for both scenarios with SAB (4096) at high density terminals only. This discounted net gain of the DABS scenario increases to $285-310M if SAB (4096) is implemented at all ATARS sites.

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APPENDIX B

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